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ABSTRACT

This document presents research studies/findings and provides a developing point of view on adolescent thought. The first chapter discusses the nature and definitions of thinking. The second and third chapters discuss frameworks for adolescent thought (focusing on the Gestalt school, Geneva school, and accelerated learning) and survey studies on problem-solving in elementary/secondary school science. The fourth chapter summarizes 13 studies undertaken at the Regional College of Education (Ajmer). Topics of studies include thinking among adolescent age science students; factorial study of adolescent thought using Piagetian tasks; problem-solving behavior in physics; growth of exclusion variables during adolescence; role of hypotheses in solving science problems; formulating/testing hypotheses during adolescence; concept formation and intellectual development; formation of experimental mind during adolescence; relationship between hypothesis testing ability in science and creativity; problem-solving ability and relative personality traits using Piagetian tasks; effect of training on stating/testing hypotheses; conservation of mass, weight, volume, and concept attainment in age 10-18 Indian students; and child's conception of movement. The fifth chapter highlights (in table form) major findings from 112 studies. The final chapter presents a current picture of adolescent thought. A full bibliography is also available from the author upon request. (JN)

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RESEARCHES
ON
ADOLESCENT THOUGHT

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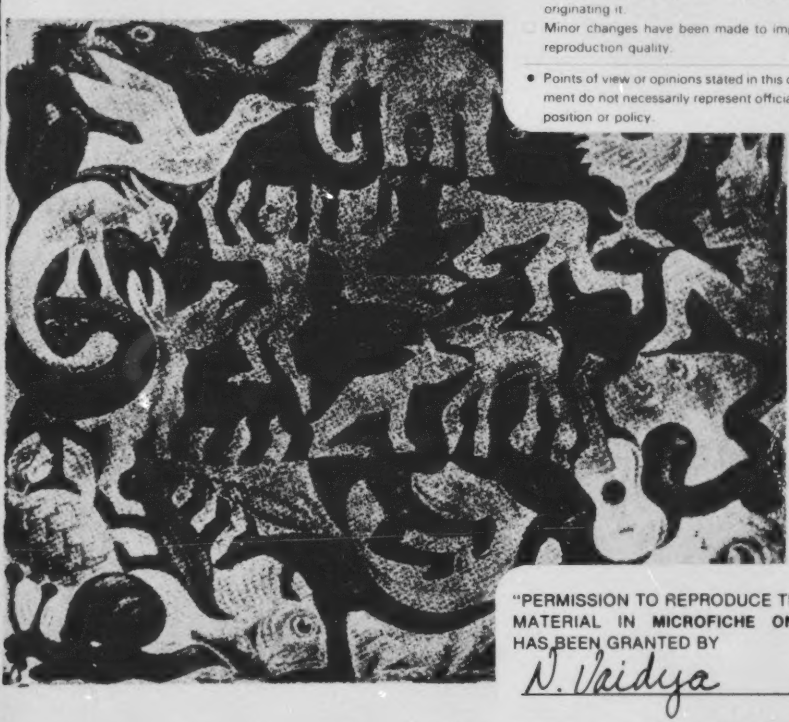

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2

RESEARCHES ON ADOLESCENT THOUGHT : A FRAMEWORK

NARENDERA VAIDYA
Professor of Education

1982

Extension Services Department
Regional College of Education, Ajmer

EXTENSION SERVICES DEPARTMENT
REGIONAL COLLEGE OF EDUCATION, AJMER

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EXTENSION SERVICES DEPARTMENT
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The Extension Services Department in collaboration with the Department of Education of the college had for some time past been publishing research reports/research papers produced by the members of the staff of this college.

Such a book is with us which has been produced by Prof. Vaidya, Professor and Head of Education Department, RCE, Ajmer. The book deals with the researches on Adolescent Thought within the Genevan Context.

The present book comprising six chapters is a contribution in this direction which also attains not only author's work but also studies conducted by his students both at tne Ph. D. and M. Ed. level, Part of the experimental work has also received financial assistance from ERIC (NCERT) New Delhi.

We are thankful to Prof. N. Vaidya for his efforts.

G. N. Bhardwaj
Co-ordinator

By the Same Author

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Teapot Algebra

Many people think that it is impossible to make Algebra about anything except number. This is a complete mistake. We make an Albegra whenever we arrange facts that we know round a centre which is a statement of what it is that we want to know and do not know; and then proceed to deal logically with all the statements, including the statement of our own ignorance.

Algebra can be made about anything which any human being wants to know about. Everybody ought to be able to make Algebras; and the sooner we begin the better. It is best to begin before we can talk; because, until we can talk, no one can get us into illogical habits; and it is advisable that good logic should get the start of bad.

If you have a baby brother, it would be a nice amusement for you to teach him to make Algebra when he is about ten months or a year old. And now I will tell you how to do it.

Sometimes a baby, when it sees a bright metal teapot, laughs and crawls and wants to play with the baby reflected in the metal. It has learned, by what is called "empirical experience", that teapots are nice cool things to handle. Another baby, when it sees a bright teapot, turns its head away and screams, and will not be pacified while the teapot is near. It has learned by empirical experience, that teapots are nasty boiling hot things which burn one's fingers.

Now you will observe that both these babies have learnt by experience. Some people say that experience is the mother of Wisdom; but you see that both babies cannot be right; and, as a matter of fact, both are wrong. If they could talk, they might argue and quarrel for year; and vote; and write in the newspapers; and waste their own time and other people's money, each trying to prove he was right. But there is no wisdom to be got in that way. What a wise baby knows is that he cannot tell by the mere look of a teapot, whether it is hot or cold. The fact that is most prominent in his mind when he sees a teapot is the fact that he does not know whether it is hot or cold. He puts that fact along with the other fact : that he would very much like to play with the picture in the teapot supposing it would not burn his fingers; and he deals logically with both these facts, and comes to the wise conclusion that it would be best to go very cautiously and find out whether the teapot is hot by putting his fingers near but not too near. That baby has begun his mathematical studies; and begun them at the right end. He has made an Albegra for himself. And the best wish one can make for his future is that he will go on doing the same for the rest of his life.

Perhaps the best way of teaching a baby Algebra would be to get him thoroughly accustomed to playing with a bright vessel of some kind when cold; then put another just like it on the table in front of him, one being filled with hot water. Let him play with the cold one; and show him that you do not wish him to play with the other. When he persists, as he probably will, let him find out for himself that the two things which look so alike have not exactly the same properties. Of course, you must take care that he does not hurt himself seriously.

Mary Boole
A Boolean Anthology
Association of Teachers of Mathematics (U.K.)

Foreword

In the context of day to day classroom instructions, the present century is more popularly called the 'century of the child'. In other words, it means that support from Educational Psychology should be obtained for imparting efficient instruction to the young. Worthwhile view points and insights have appeared in the psychological literature from the angle of learning theories. About thirty years ago, educators hardly talked beyond Gestalt psychology. Whereas there was abundant literature on thinking as applied to the education of young children, there was little to report on same in regard to the nature and development of adolescent thought.

With the publication in '1958' of the 'Growth of Logical Thinking' by Professor Jean Piaget and Professor Barbel Inhelder, in Europe, worldwide interest arose on the investigaion of adolescent thought. Since then, several researches by several workers have been appearing in different parts of the world. Efforts to document these researches are there but the outcomes have been quite sketchy.

Professor N. Vaidya has been working in this area for the last twenty years or so. He and his students have done considerable work in this area which has been summarized in the overall context in the present publication entitled : 'Researches on Adolescent Thought' : A Framework'. It attempts to describe learning theories in brief, consolidates studies by Professor Vaidya and his students, presents research findings of several foreign workers engaged in similar work and lastly, provides a developing point of view on adolescent thought.

How to educate for the development of logical thought at school is a serious problem with us these days. Education for concept development, skill acquisition, problem solving and creativity is being talked of in a big way in our times, this country being no exception. But there is little to fall back upon so significant a field as Educational Psychology when it comes to obtaining psychological support for the same. Books on methodology of instruction simply skip this issue, This actually is the true state of affairs, particularly in our country. Currently, the Piagetian model is a mine of ideas which need to be exploited at the earliest. It should not be lost sight of that others like Professor B. F. Skinner, Professor Robert Gagn'e, Profssor J. S. Bruner and Professor Ausubel have also talked of new ferments in education The ideas of a Russian psychologist L. S. Vygotsky are also in the air in certain parts of the world. So, a new synthesis is possible which may draw heavily from the Piagetian pool.

Learning by doing also advocated in the Gandhian system of education-through thinking, stands highly enriched. This publication, I believe, is surely going to help in the formation of this well sought goal, in not too distant future.

March 26, 1982.
Regional College of Education,
AJMER

S. N. DUTTA
Principal

Preface

Science and technology in this century have become the growing edges of our society which almost keep us out of tune with the times in which we live. Within the context of schooling, education for concept development, problem solving and creative behaviour have become the slogans of the day which are least understood even now. Why ? Because the true aim of education is to discipline and train the mind rather than to furnish it with information and nonfunctional knowledge to the use of its own powers. As late as 1958, Professor Jean Piaget (1896-1980) remarked about the nonexistence of any significant study on adolescent thought. Since man will not cease from exploring, several workers all over the world struck off their sparks against the hypothesized Piagetian territory which when aggregated appear to illumine the area dimly somewhat as follows :

1. The human mind is highly dynamic. It naturally processes quite a bit of spontaneous thought which needs to be explored for all practical purposes for advancing human thinking.
2. Like Piaget, teachers should listen more and more to the inaccurate answers of their pupils and consequently improve their strategies and tactics of teaching based upon the knowledge, thus, gained.
3. The concrete operational stage is quite dominant among normal adolescent pupils.

4. Children stick to their thoughts firmly. When compelled to think, their erratic thought in several contexts appears to suffer hump before individual concepts finally settle down.

5. Whereas the adolescent pupils are in a position to state hypotheses, they are not in a position to test them. The same is equally true of exhausting all the possibilities. At best, they can test one variable at a time in most of the cases.

6. Content, context and instructional intention are some of the factors which influence learning. Also pupils use words metamorphically. All these make access to child mind difficult.

7. Role of past experience as well as hints and cues is little understood in problem solving. The opinion is also more or less divided on sex differences in problem solving.

8. The psychometric and developmental studies on intelligence have yet to converge. There is still a distinct possibility of the existence of a fifth stage gearing to aptitude variations and career commitments.

The present publication comprising six chapters is a contribution in this direction which also attempts to determine the mathematical structure of adolescent thought through factor analysis. The first chapter discusses nature and definitions of thinking. The second and third chapters deal with frame work for adolescent thought and individual studies conducted in the area of school science. The fourth chapter contains ten out of thirteen intensive studies undertaken at the Regional College of Education, Ajmer. The fifth chapter reports at one place over one hundred thumb-nail studies and their findings. The last chapter tries hard to portray the developing picture of adolescent mind. A full bibliography in print is also available from the author on request.

The author shall feel his efforts amply rewarded if this work succeeds in stimulating others in fusing the two currently apparent diametrically opposite points of view in understanding the real nature of intelligence.

March, 1982 Narendera Vaidya

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My gratitude is extended also to the contributors of this volume as well as the other researchers whose works contributed immeasurably to the contents of this volume. Last, but not the least, I am very much obliged to Miss Padmini, M.S ERIC (NCERT) Project Fellow, and Mr. V.P. Agarwal who helped me a lot in the Physical preparation of this book.

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4. The Growth of Exclusion of Variables During Adolescence-A Study.
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7. Some Aspects of Concept Formation and Intellectual Development.
8 The Formation of Experimental Mind During Adolescence.
9. A Study of Relationship Between Hypothesis Testing Ability in Science and Creativity.
10. A Study of Relationship Between Problem Solving Ability and Some Relative Personality Traits Using Piagetian-Type Tasks.
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Chapter I

Nature and Definitions of Thinking

Since, the time of Aristotle, philosophers and logicians have not only investigated thinking in terms of its product but also have developed their own laws of thought. Examples are; Laws of Identity; Contradiction; and Excluded Middle. At the turn of the century, psychologists placed lot of faith in faculty psychology which regarded mind as made up of several individual abilities, each amenable to training in isolation. Initial success with it resulted in the theory of formal discipline, a major educational achievement which was exploded later on. The pure psychologists both European and American, investigated thinking from their varied stand points with little attention paid to problems of classroom instruction. The educational psychologists, on the other hand, examined thinking through the medium of problem solving but the actual process of thinking eluded their attention (4). For example, C. E. Spearmen regarded the following three principles of significance : "apprehension of experience, education of relations and education of correlates" quite sufficient for explaining the entire spectrum of intellectual behaviour (5). On surveying the relevant literature, it appears that the following aspects of thinking have received attention over the years, that is, the term thinking has been referred or applied to : "abstracting, analysing, comparing, conceiving, deducing, defining, estimating, generalizing, guessing, imagining, judging, knowing, opining, reasoning, recalling, recognizing, reflecting, remembering, searching for conclusions and understanding, a sort of general meaning. In its restricted use, the same term has been applied to 'determined course of ideas, feeling, formulating and assertion of propositions; percepts and vocal sound" (6). Symmond has listed nineteen types of thinking such as learning, meaning, stating relationships, defining etc (7). Humphrey has equated it with problem solving (8). Burt and his students, have regarded it a 'hierarchy of thinking abilities comprising relation, association, perception and sensation' etc. (9). Gestalt psychologists have emphasized its perceptual and problem solving aspects (10). Bartlett has regarded it as high level skill in which 'symbols, words, numbers, shapes, colours, tones, supplement and may take the place of bodily movements" (11). E. A. Peel has distinguished among four kinds of thinking : Thematic, Explanatory, Productive and Integrative and adds that "free association, remembering, reverie, fascile associatiation, punning, solving cross word clues" are other aspects of human thought, which have not been classified in any one of the above mentioned categories (12). D. H. Russell has suggested his own scheme starting with stimulus patterns (internal or external) through materials of thinking (perceptions, images, memories and concepts), processes in thinking, (perceptual thinking, associative thinking, problem solving and creative thinking) to products of conclusions implying thereby that abilities in thinking, techniques, habits and devices are amenable to learning. (13). In the Encyclopedia of Educational Research, Wilhelm Reitz, while surveying the area of thinking, has hypothesized that whereas the materials of thinking are numerous, the number of processes appear to be few; and here, 'research data being incomplete and scattered" (14). From the above it is clear that it is pretty difficult to define thinking and even when defined, its explanatory concepts themselves become and consequently require further explanations. The whole position on thinking is well summarized in the words of Hearnshaw in Recent Studies in the Psychology of Thinking :

Thinking-highly organized and balanced activity dependent upon the coordination of a large number of subordinate activities under favourable conditions is inseparably linked with the personality traits of its thinker. This complex activity is difficult to investigate if it remains ghost-like but, on the other hand, if it is regarded as a skill (or a group of skills) which is organization, "a view point quite in conformity with Piaget's genetic findings, with the evidence pointing to the motor accompaniments of thought and the results of perceptual studies emphasizing the dynamic nature of perception and the acquired character of all but the simplest perceptual structures'; then it is possible to investigate thinking by trying to bear upon the psychology of thinking all that the psychologist has learned about learning keeping in mind that skills are essentially activities and skills are learned and their basic feature is organizations.

The central question on thinking has been very excellently put by Hearnshaw for it is possible to study both the processes of generalization and discrimination experimentally, a step ahead of 'deu exmachina' in the form of insight propounded by Gestalt psychologists (14)

It will be irreverent if John Dewey's contribution in narrowing down the concept of thinking as problem solving is not acknowledged by which he avoided the 'pitfalls of both traditional empiricism and apriori rationalism' (15). He, thus, brought out Ryle's ghost in the machine for empirical examination tied to purpose and consequently subject to reflection. He regarded thinking as a function of an 'obstacle in the way of goal directed activity' (14). To quote Dewey :

> Sensory qualities experienced through vision have their cognitive status and office, not (as sensational empiricism holds) in and out of themselves in isolation, or as merely forced upon attention, but because they are the consequences of definite and intentionally performed operation. Only in connection with the intent, or idea, of these operations do they amount to anything, either as disclosing any fact or giving test and proof of and theory. The rationlist school was right in so far as it insisted that sensory qualities are significant for knowledge only when connected by means of ideas, But they were wrong in locating the connecting ideas in intellect apart from experience. Connection is instituted through operations which define idea and operations are as much matters of experience as are sensory qualities (15).

He thus stripped Thinking of its philosophical aspects as outlined by Descartes, John Locke and J. S. Mill; and gave it a form of physical process of natural sciences manifested in man while coping with his environment (14). On the basis of introspection, he suggested five steps in thinking which can quite adequately explain most of our thinking. This lead by Dewey has been further followed by many practical workers in the field, a few to mention are : Burt (1928); Johnson (1944); Polya (1945); Humphrey (1948); Bloom (1950); Burrack (1950); Hoffman and his Co-workers (1951); Vinacke (1952); J. Stanley Gray (1956); Mill and Dean (1960); Oad and Vaidya (1975). It should not be lost sight of that these steps have been hypothesized for the sake of convenience (17). One can identify a number of stages in thinking depending upon the nature of problem to be investigated (17). For illustration, let us consider the steps as suggested by Dewey, Humphrey, Mills & Dean and Oad & Vaidya.

Dewey (1910).

(a) A felt difficulty.
(b) Its location and definition.
(c) Suggestion of possible solution.
(d) Development of reasoning of the bearing of suggestions.
(e) Further observation and experiment leading to its acceptance or rejection (15).

Humphrey (1948).

Directed thinking involves :

(a) A Problem Situation.
(b) Motivation factors.
(c) Trial & error
(d) Use of association & images.
(e) A flash of insight.
(f) Some application in action (1).

Mills & Dean (1960).

(a) A difficulty is recognized
(b) The problem is clarified and defined.
(c) A search for a clue is made
(d) Various suggestions are made and are evaluated and tried out.
(e) Whereas practice in the definition of problem involves problem survey, problem description, problem discussion, problem limitation, planning for action and further analysis and limitation (16)

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Oad & Vaidya (1975)

(a) The appearance, disppearance and appearance of the problematic situation.
(b) Vague understanding and clarification of the problematic situation.
(c) Blunt Formulation of the problem.
(d) Trial and error attacks.
(e) Proposing hypotheses.
(f) Screening hypotheses and selecting testable hypotheses.
(g) Testing hypotheses through control experiments.
(h) Obtaining relevant hypotheses.

Mathematizing
Insight into the
nature of proof
Determining limiting situations.

Verification
Exploring further
varied experimental
materials exploring
further varied methods
of attack.

Final formulation of the
problem and its solution.

Application

Repetition of the cycle in the face of unknown difficulties (16)

It may be mentioned that these steps like logically obtained educational principles not only do not clarify any psychological principles but also do not follow each other in a fixed sequence. They are, in fact, 'simplified, idealized versions of what may take place in problem solving' or reflective thinking. They are more in the nature of heuristic methods rather than logical proofs. They only help us to see the problem a bit more transparently in all its varied aspects. Karl Duncker through his studies on Problem Solving, gave these steps the more generalized name of Search Model which may be little different from Strategy (Goodnow, Austin & Pruner) and Key Factor as propounded by Guilford, Merriefield Christensen and Frick in 'determining efficiency of creative thinking' (18). Lastly, with special reference to school subjects, Peel distinguished among four kinds of thinking, namely, Thematic (free from any practical requirement); Explanatory, Productive and Integrative (11). Productive Thinking comes very close to Thinking when it is equated with problem solving. It is said to have taken place' when the attack on a problem is taken beyond the stage of explanation and used to modify the situation so that the original problem is removed' (6,11). In one form or another, it enters into every school subject. Its chief distinguishing features, according to Peel, are :

(a) It contains an element of forward thinking,

(b) It becomes effective by changing the problem situations materially in order to achieve solutions.

(c) Some new problems may be solved by restating them in the light of established knowledge.

(d) These situations may be material, social or personal (11).

From the above account, it is safe to conclude that it is not possible to define thinking operationally even in the highly restricted sense but it is still possible to guess what it is not in that context. In other words, it is a task oriented situation, which stimulates thinking right from the moment the task is presented to the subject until the moment it is finally solved by him. The problem is not that simple as the following section on, 'Problems Posed in the Field' will show.

Problems Posed in the Field

It is necessary to go ahead on the journey of investigating thinking itself for the venture may pay off in the long run. Where to start ? and which road to take ? are the basic problems to be tackled first before taking the first step on this journey whose end is unknown. George Humphrey in Fifty Years Experiment on Thinking remarked that the entire past adventure on thinking has not been at all fruitless for we now know, at least, the kind of road we have yet to travel (1).

Thinking in relation to the past history of the individual. Or 'what makes people attack problems', according to Cohen, will contribute to our understanding of problem solving (19). According to Johnson, an adequate understanding of problem solving requires 'knowledge of the development of even higher organization (as compared to concept formation) of data such as the concept of self, points of view, frames of reference, and more complex patterns of inter-relationship illutsrated by the family pattern, the syllogism and the pattern of industrial experience' (6). For Vinacke, the whole area awaits invasion through case study approach with a view to collect as well as to interrelate as many aspects of performance as possible in as many situations as practicable (6). Similarly, Carl P. Duncan, D. Wheeler, E. A. Peel, R. H. Ennis, M V. Travers and F. G. Watson have emphasized the importance of investigating thinking (problem solving) in relation to some outside variables like intelligence, personality characteristics, socio-economic status, motivation, ego involvement and set, a few out of the many to mention (20).

Along with these variables, it is also necessary to study generalization of formal reasoning of thinking in Gestaltean as well as Piagetian Contexts. Secondly, very little is known about the overall psychological structure of any school subject. Thirdly, these individual studies are required to be carried out in as many different subjects as well as situations as possible. Fourthly, the stage concept as propounded by Piaget also needs to be investigated at depth along with the emergence of various mental operations at various age levels. Lastly, there are several difficulties, which need to be tackled or mastered before we can understand clearly the nature of thinking : problem solving, concept development and attainment. Here, the main difficulty lies in our failure to understand the sequence of reasoning from the very early childhood to late adolescence, not only within each age-group but also across the various age-groups over a very wide I. Q. range. It is of interest to point out that even the restricted behaviour like problem-solving, according to A. Dietz Maureen and George D. Kenneth, has been investigated under various definitions (21). The field of human thinking as a whole poses certain fundamental problems which are yet to be investigated even partially before we can fully understand the basic assumptions underlying human thought processes (20). It is very likely that answers to these questions will have an import equal to the concept of Periodic Table in Chemistry or the concept of Quanta in Atomic Physics for the whole field of psychology as well. Let us now state below a few problems posed in cognitive psychology and the psychological structures of school science by the various workers.

(a) Piaget is a mine of ideas on cognitive thinking, necessitating vast experimental educational research. He goes far beyond on the nature of intelligence, what A. Binet characterized wittily as 'It is what my tests measure' (23). In addition to the role of experience, it is necessary to have information on the extent of adult's influence on children as well as their mutual influence on each other. Not long ago, J. S. Bruner said that, in principle, anything can be taught to anybody in some honest form. This principle further needs to be examined empirically for Does it Imply Elimination of Sequences ? To quote the large problem which first needs to be understood developmentally rather than psychometrically in the words of Jean Piaget in the Growth of Logical Thinking and Main trends of Research in the Social & Human Sciences (Part I) :

(i) It is surprising that inspite of the large number of excellent works which have been published on the affective and social life of the adolescent-we hardly need remind the reader of the studies of Stanley Hall, Compayre, Mendousse, Spranger, Charlotte Ruhler, Landis, Wayne Dennis, Brooks, Fleming, or Debesse, or those by psychoanalysts such as Anna Freud and Helene Deutsch, and by sociologists and anthropologists such as Maulinowski and Margaret Mead, not to mention others-so little work has appeared on the adolescent's thinking (22).

(ii) As to the theory of intelligence, all these observations seem to lead to a number of conclusions that it is difficult to ignore. The first is that the intelligence is much richer than the aspects of which the subject becomes aware, for he is conscious only of the external findings of his intelligence, except, when through a systematic and retroactive

> reflexive process, logic and methematics formalize, but generally without concerning themselves with their sources, structures whose natural roots are already in the intelligence in action. As to the average subject, he is aware of this intelligence only from its performance, for the operative structures elude him, as more over nearly all the mechanisms affecting his behaviour and even more so his organism. It is, therefore, for the observer to find out whether the structures do exist and to analyse them, but the subject is unware of them as . structures discern only the operations used by him (and even then not all of them, for he constantly resorts to 'associativity' and 'distributivity' without realizing it, and the same is often the case with commutativity)....

We had to wait for psychogentics and the discovery of the various preoperative and operative stages through which the child and the adolescent go before the specificity of intellectual structures could be established. However, this structuralism is only one of the two services rendered by psychogentics. The other relates to constructivism and is not less essential. The operative structures of the intelligence are not innate, but slowly develop laboriously during the first fifteen years of life in the most favoured societies. If they are not already formed in the nervous system, neither are they in the physical world, where they would only have to be discovered. They therefore, testify to real construction, proceeding by stages, at each of which the results obtained at the preceding stage must first be reconstructed before the process can be broadened and construction resumed. The nerve structures serve as a medium for the sensorimotor intelligence, but the latter builds a series of new structures

(permanent object, group of transfers, patterns of the practical intelligence, and so on); the thought processes are based on sensori-motor action, from which they are derived, but they reconstruct into representations and concepts what was acquired in practice, before broadening considerably the range of initial structures; reflexive and abstract thought restructures initial mental operations by placing the concrete into the sphere of hypothesis and propositional or formal deduction. In the creative adult, this movement of constant construction continues accordingly as shown, among other things, by the forms of technological and scientific thought (23).

(a) Kenneth Lovell, while carrying out several studies on developmental processes in thought among children varying widely in age, intelligence and culture, has suggested several problems which cry for solution for their solutions are of direct relevance to development of effective curricular programmes Some of these problems are :

1. What is the role of experience (physical and mathematical) in intellectual development of children ? How is it to be handled ?
2. Like Head Start Schools in U. S. A., what is the long term influence or impact of early stimulation of the culturally deprived and of certain types of school educable retarded children ?
3. What is the effect of variables like emotional life (fantasy); teaching and learning techniques based upon Piaget's work, culture and subculture patterns and the restricted functioning of any scheme within a given area of knowledge at one time on cognitive growth ?

Lastly, he adds that lot of information is needed 'regarding the growth of more advanced concepts in mathematics and science, e g , function and entropy' (24).

(c) Michael A. Wallach, while reviewing research on Children's Thinking; regards the contribution of the Geneva School quite monumental, with a close blending of empirical description with theoretical speculation. He refers to the study of P.R Hofstaetter on The Changing Composition of Intelligence in which he has shown structural changes taking place, using a highly mathematical technique called factor analysis. He then adds :

> .... It is apparent, therefore, that the point of boundary between Thinking and Learning is, to at least some extent, arbitrary. Several other research directions may be mentioned, all concerning aspects of thinking which have yet to be extensively examined from a developmental point of view. These include fantasy and curiosity in cognitive activities, the related topic of originality, inventiveness, or creativity in thinking; and variation in aspects of thinking as related to factors of personality and motivation, to parental attitudes, and sex of the child ... ... Perhaps the most striking general conclusion to be drawn from the developmental information we have reviewed in this chapter is that the human's basic categories for analysing physical reality are a product of slow and laborious construction (5).

(d) E. A Lunzer while disposing of Byrant's criticism of Piaget in the Piaget Controversy makes a few specific points requiring our urgent attention for investigating thinking. First, it is necessary to seek information about the extent to which specific gains obtained in specific settings can be generalized to wider settings. Secondly, just for the sake of novelty, one type of drill, say, number, should not be replaced by, say, drill in conservation of numbers. Thirdly, rules of thumb procedures, of course, necessary do not solve our entire educational problems for life presents quite different problems. Fourthly, the theoritical and practical educational implications of Piaget's work on thinking and learning are narrow and limited for they do not fully solve problems faced by educational psychologists and the practising classroom teachers. It is of interest to point out that only a small amount of variance in scholastic performance is accounted for while considering the three levels of operativity as envisaged by Piaget. Fifthly, it is necessary to investigate the relationship between thinking and operativity; range of response at the given level of operativity and the distinction between levels of tasks and levels of children's thinking as argued by J. S. Bruner. It is quite possible that a simple logical experiment like the one used by Watson may fail to evoke formal behaviour from the graduates. He then adds :

> Piaget draws attention to an important difference between associative learning (learning facts and certain skills) and the learning which leads to a restructarization. Or, as we might say, a reprogramming of approach strategies in relation to complex tasks. But to recognize that there is a difference is not enough. What are the relations between intelligence, learning ability and the development of logical thought ?.... At the very least, a knowledge of the changing patterns of inter-correlations among a wide variety of tasks (learning, problem solution, memory, attention, language, etc.) should offer some leads.

In the end, of course, statistical correlations are not enough. What is required is an over all model, supported by experiment, within which what we call learning, intelligence and thinking will be redefined. More than one break through is needed to achieve this. When it is achieved, Piaget will have been superseded. But not in the sense that his findings will have been shown to be spurious. Only that the perspective, broad though it is, is still too narrow and too imprecise (26).

(e) It is pertinent to consider the logical structure of any school subject. Specifically speaking, in case of science, scientific knowledge is exploding at an accelerated rate in each decade towards the closing half of the twentieth century. This, in itself, is creating lot of problems for curriculum maker at all levels of education. Perforce of circumstances, he is compelled to search for the most powerful concepts (still evolving) which build up the picture of, say, physics, in our times. This guided the very rationale of P.S.S.C. in terms of providing powerful concepts capable of transfer in wider contexts with a view to present a complete picture of physics G.C. Finlay has aptly remarked:

> The Committee has chosen to select subject matter and organize it with the intent of providing as broad and powerful a base as possible for further learning, further learning both in and beyond the classroom. Through its materials, the Committee seeks to convey those aspects of science which have the deepest meaning, the widest applicability.
>
> The explanatory systems of physics and how they are made have much more forward thrust as educational tools than the individual application and the discrete,

> unconnected explanation. Thus the PSSC has chosen for its subject matter the big over arching ideas of physics-those that contribute most to the contemporary physicists' views of the nature of physical world.... The power of big ideas is in their wide applicability, and in the unity they bring to an understanding of what may appear superficially to be unrelated phenomena........ Pedagogically this choice has virtues........Principal among them is the acquisition of criteria by which subject matter can be selected and organized toward the coherence the subject itself strives for (27).

Mathemetics is also undergoing the same development. At this point, David P. Ausubel intervenes by suggesting the use of Advance Organizers for enhancing learning by taking the maximum advantage of the Big Ideas of Science in the form of 'subsidiary facts' concepts and generalizations subsumed under them '(28). It is implied that the 'Organizers make use of established knowledge to increase the familiarity and learn-ability of new material, and also take into account children's misconceptions about and folklore models of physical and biological causality' (27). In contrast to this, Robert Kraplus has designed three different types of lessons, namely, exploratory, inventive and discovery for developing scientific concepts among elementary school children in the Science Curriculum Improvement Study Project under the influence of the Geneva School (29). J. S. Bruner has talked of Teaching Science as a Tool subject (30). Currently, Science education method specialists : A.R. Hibbs and J. R. Suchman have advocated the acquisition of general inquiry skills, appropriate attitudes about science, and training in the Heuristics of Discovery' (31) The result of all this is that the two dimensions to the content and form of science have become very active which on the very surface, appear to be conflicting. It is a very serious problem for the very basic data obtained in the context of new generation projects are expected to challenge our age old educational notions because of its being entirely new, novel and exciting, pointing to radically different concepts potentially applicable to the teaching-learning process (32) To quote J. S Bruner :

> Unbridled enthusiasm for audio-visual aids or for teaching machines as panaceas overlooks the paramount importance of what we are trying to do. A perpetual feast of the best teaching films in the world, unrelated to the other techniques could produce bench bound passivity (32).

(f) Reference has already been made to the Revolution in Science Teaching. Lee J. Cronbach, while discussing the Psychological Issues and Recent Curriculum Reforms, says that the seniors at the college, after a long period of absence, have returned to their juniors working at schools, with a view to help them how to familiarize the youngsters with the nature of scientific or mathematical thought;

> My message has been that psychological knowledge is inadequate to answer the questions, now being posed by educational leaders. Part of the fault has been our over-confidence. We have failed to realize that traditional experimental designs made it impossible for us to ask vital questions. Moreover, there has been a great deficit of research on educational learning since 1920. Today, we find a happy conjuction of demand for psychological knowledge, new interest among psychologists in cognitive processes, and challenging matters to investigate (33).

In continuation, Jerome S. Bruner, indirectly hints at the problems to be investigated which in a way are more philosophical than psychological or technological for they reflect the type of vision that we hold for the end-products of our educational efforts. He says :

> Much of the learning in our classrooms is atomistic and episodic; children learn one fact here, one fact there. This sort of curriculum is made up of separate units, each a task into itself "We have now finished addition; let us how move to multiplication." I do not wish to make it seem as if our present state of education is a decline from some previous Golden Age. For I do not think there has ever been a Golden Age in American public education....The volume of positive knowledge increases at a rapid rate. Atomizing it into facts to be filed is not likely to produce the kind of broad grasp that will really help. One of the principal objectives of learning is to save us from subsequent learning. When we learn something, the objective is to learn it in such a way that we get a maximum of travel out of what we have learnt. If the principle of addition has been grasped in its generic sense, it becomes unnecessary to learn multiplication, for, in principle, multiplication is only repeated addition. Learning something in a generic way is like learning over a barrier, on the other side of which is thinking. When the generic has been grasped, we are able to recognize new problems as exemplars of old principles we have already mastered. A significant aspect of the human mind is its limited capacity for dealing at any one moment with diverse arrays of information. We must, therefore, condense this information to that having general significance (34).

Concluding Statement

It is evident from the above mentioned problem statements that the above mentioned basic problems in one form or another are being encountered at different levels. Both researchers and practitioners are asking a different sort of question but with the same general objective in mind. Specifically speaking, the working teacher wishes to know how to present the subject matter of science to the youngsters with a view to develop their thinking. The curriclum builder, while insisting on the inquiry approach, wishes to know the order of subjects or parts there of to be approached respectively by him as well as by his pupils.

The subject matter specialist at the research level is engaged in finding the most powerful scientific concepts which could trigger off young Children's minds in the direction of the subject. The cognitive as well as the method specialists wish to relate the mental development of children to the most powerful scientific concepts with or without the use of appropriate first hand experiences, by determining the 'transfer value of statements of principles given to a subject, as contrasted with individually derived principles' (35). The philosophers of science wish to relate our work with fundamental purposes of human life so that no violence is meant as well as done to young learners. In a restricted frame of reference, it is a three tier problem involving research on the origin and growth of thought processes, methods of teaching (use of instructional and illustrative material also included); and the continual selection of the most powerful basic concepts relevant to teaching learning process in the wake of recent revolution in scientific knowledge. Naturally, a very broad frame of reference is needed to answer these little understood problems which can only be built up if there were already a good number of specific studies in each of the above mentioned areas which when integrated will surely succeed to illumine the very basis of human thinking. At present, it is a pious hope as the next chapter will show. The present documentation is an attempt in that direction (35).

SURVEY OF RELATED STUDIES ON PROBLEM SOLVING IN SCIENCE

Chapter II

Survey of Related Studies on Problem Solving in Science

Introduction

Latin Poet Terence once remarked, "Being human myself, I regard every thing to do with human beings as my concern" (36). It is an excellent remark applicable to human thinking, learning, adjustment and attitude. Speaking restrictedly, it can be very safely said that our knowledge about how children learn science is very little. Yet it is a fact that learning goes on in a big way among humans and, to a varying degree, in animals as well. It may be provoked by new and novel material, repeated presentation of the same in different ways, opportunities for practice and individual curiosity (37). Like Peel, E. A Lunzer then poses several problems which need to be answered by the researchers; conditions for learning maximally, amount of practice, the nature of learning, the contextual operation of intelligence (for example, rapidity in learning) and the nature of difficulties underlying various learning tasks (38). It is also well known that we least make use of the basic concepts drawn from the various learning theories and the well known empirical studies including action research in our day to day instruction (38) Even in this decade, no serious and sequential effort has been made to select even few concepts, demonstrate and illustrate them under all possible conditions, for as many school subjects as possible, encountered at school right throughout the school (39). Research of the practical type relevant to the teaching of various school subjects including science and mathematics is little in this country (39). Even in literature, ideas lie scattered here and there which when consolidated should help us a bit in relating the mental development of children to the powerful concepts of science. It is therefore necessary to see the problem of human thinking in the following eight theoretical standpoints out of which the last three are of much significance in view of the scope of this study :—

*1. S. R. Theories.
*2. Gagne's Viewpoint.
*3. Phenomenological Theory.
*4. Factor Analytic View.
*5. Information Processing.
6. Gestalt School.
7. Geneva School.
8. Accelerated Learning.

1. Gestalt School

Wurzburgers were the first to investigate the thinking processes experimentally and, in fact, developed their own method called 'systematic or experimental' introspection (40). They were not interested in problem solving as such but confined themselves to such questions as 'what is the consciousness when we are thinking of ?' "Why does a subject start thinking ?" They consequently considered consciousness as passive entities (25). They also did not distinguish between productive and reproductive knowledge (or thinking as the same laws applied to both). As a more fruitful and productive model appeared on the scene, the whole approach of Wurzburg school fell 'like a house of cards silently and without any resistance' (40).

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*Deleted from discussion.

This productive model was the Gestalt psychology whose leading figures were Wertheimer, Kohler, Koffka, Duncker and Lewin. They violently attacked the prevailing association psychology; structuralism functionalism and behaviourism then prevailing in America; and in simpler words denied the possibility of interactions of simpler bonds developing into intelligent as well as purposive behaviour. It is a paradox that this school is deeply rooted in philosophy; and physiology which was little developed at the beginning of the present century. If we avoid the controversies, two key concepts in relation to science teaching appear in literature, these being Insight and Productive Thought.

Features of Gestalt Psychology

(i) Perception is superior to sensation. Laws underlying perception extend not only to thinking but also to the objects of thought.

(i i) It is neither additive nor summative of either process or product. Whole is not simply the numerical aggregate of its constitutents

(iii) Behaviour always takes place in an environment. Psychological processes operate in the present field which are subject to Gestalt forces; symmetry, continuity, proximity, closure and good form etc.

(iv) Psychological field is not mystic for a corresponding field functions in the brain, that is 'interaction occurs among the brain correlates of the perceptual facts in question.' These two processes are, in fact, isomorphic (parallel) which imply equality of structure, thus, making a physical physiological explanation of psychological organization.

(v) There is least stress on memory and past experience (41).

They have emphasized the dynamic nature of the field and then posed main problems underlying thinking or more restrictedly speaking, problem solving or productive thinking. Being dissatisfied with the existing approaches of traditional logic and association theory, Wertheimer posed to himself the following question and then attempted to answer it as well :—

> What occurs when, now and then, thinking really works productively ? What happens when, now and then, thinking forges ahead ? What is really going on in such a person ? These are not easy questions to answer when solution depends upon observing such processes as they actually go on in the mind.
>
> What really takes place in such processes ? What happens if one really thinks, and thinks productively ? What may be the decisive feature and steps ? How do they come about ? When the flash, the spark (42) ?

He goes on to speculate about conditions, favourable and unfavourable that influence attitudes towards thinking; good or bad; and the methods of improving it. Then he poses problems for the development and improvement of thinking in a manner which have direct implications for the effective teaching of school subjects, comparable to that of 'Operational Research' or 'Museum of Defects', the two popular key concepts in industry. He asks; "Suppose we were to make an inventory of basic operations in thinking-how would it look ?" "What basically is at hand ?" Could the basic operations themselves be enlarged, improved and then be made more productive" (42) ? Lastly, he tried hard to distinguish between structural and non structural solutions when he discussed some problems relating to paralellograms, sum of the angles of a polygon and summation of series which are well known in literature. In this thought provoking discussion it remains unclear how the non structural solution changes into a structural one for Koffa rephrases this problem again when he says," How does a problem find its solution, how does the stress set up by a question contrive to create those conditions which make the answer possible" (43) ? He adds further : "The problem of the arousal of a new process is not in all cases a problem of traces" (43). The immediate cause is still shrouded in mystery for this problem has been duly recognized by Wertheimer, Duncker, Maier & Claparede (43).

Problem Solving. Particularly speaking, let us now refer to the work of Duncker on problem solving. Using problems of practical variety having clear cut solutions, he stated his main thesis as follows :—

> In the present investigation, the question is : How does the solution arise from the problem situation ? In what way (s) is the solution of a problem attained ?.... A problem arises when a living creature has a goal but does not know how this goal is to be reached Whenever, one cannot go from the given situation to the desired situation simply by action, then there has to be recourse to thinking. (By action we mean the performance of obvious operations). Such thinking has the task of devising some action which may mediate between the existing and the desired situations. Thus the solution of a practical problem must fulfil two demands. In the first place, its realization must bring about the goal situation; and in the

second place, one must be able to arrive at it from the given situation simply through action (44).

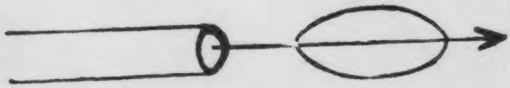
At every moment during the course of problem solving, the direction of a solution-process depends on the psychological relief map of the problem situation the disposability and the looseness of the elements constituting the problem. Two of his world famous problems as quoted in literature are mentioned below :

(a) The Compensated Pendulum.

You have seen a pendulum. The slowness or fastness of the pendulum depends upon its length-the distance between the point of suspension and the centre of gravity of the bob. In winter, this length decreases and the clock goes fast and vice versa in summer. But we want the clock to run with absolute accuracy. How can be this defect remedied ? Lastly, we are 'only concerned with the length of the pendulum for the rest, the pendulum may have any appearance at all'.

(b) The Stomach Tumour Problem.

There is a patient suffering from an inoperable stomach tumour. Radiation at different intensites is available. The problem is to treat the tumour without destroying the healthy tissues surrounding it. What can be done ? (44)



Case study approach is employed. The method of procedure is quite simple. The subject is asked to speak aloud all the ideas (both sensible and otherwise) which strike him during problem solving. Further, the subject is free to question the experimenter whenever the former is in doubt or does not feel completely informed about the problem under attack All the responses emitted by the subject are recorded This dialogue continues till the problem is solved partially or fully or when the subject gives up. The following conclusions emerged from his studies;

(i) One solution is as good as any other solution so far as the 'way out' of the problem situation is concerned. What is reflected, in fact, is the degree of the acceptance of the demands of the problem. Extraneous considerations enter into the problem situation when the essential aspect of the problem is not grasped.

(ii) Duncker then distinguishes between functional solution and the specific solution The functional solution may be right or wrong. It only reflects the general range of approach or even availability of ideas on a particular problem. At the specific execution of the solution stage, the problem is simply to fill in the minor details only He then goes on to distinguish between meaningful errors and stupid errors. The former arise in the specific execution of the right idea and the latter ones arise when the grasp on the problem is either absent or too poor. He is then able to distinguish between organic solution and mechanical solution by the type of behaviour shown by the subjects during problem solving (In the final written form of the solution, this distinction is very difficult to maintain and Duncker is aware of this difficulty). The organic solution is meaningful, less elegant, long and time consuming whereas the mechanical, solution is concise and follows a set pattern. More over, in the case of an organic solution, one sees clearly the evidence for the analysis of the goal, analysis of the situation or conflict ("where is the ground of the trouble" ?) and analysis of the material. For instance, Piaget's work on number shows the concept of mechanical solution in the case of children who compute accurately without even understanding the basic ideas, a finding consistent with John Holt (45).

(iii) Generally speaking, in the case of a successful solution, each response to the problem situation is in fact the reformulation of the problem developing organically. In prospect, it is the nature of another problem (Concretization of the goal) and in retrospect, the nature of a partial solution to the problem. The formulation of the problem more productively then implies the emergence of one or more than one functional solutions where a specific statement or a series of specific statements leads to the final form of the solution or solutions.

(iv) Cues and hints are only understood when they approach the genealogical line under development, a finding consistent with the Law of Anticipation as stated by Selz. According to it, success favours that operation which 'anticipates the schematic anticipation of the solution' approaching fully its anticipation (46).

(v) Solutions learnt mechanically, that is, without understanding tend to be forgotten in the near future. Past experience then does not guarantee success because the very essential of the problem was not grasped then.

Productive Thought & Insight. Gestalt psychology had its origin in the field of perception and the Gestalt Laws developed here were found to be applicable to learning, thinking and thought processes. According to Gestalt psychology, 'thought was not an unaltered return of the previously learned experience', as hitherto considered (40). Even the very recall of the solution would depend upon the prevailing conditions (41).

We have already referred to structural and non structural solutions as pointed out by Wertheimer for behaviour is not blind as it is "sensitive response to the structural relations existing in the situation as a whole" (44). Duncker and Katona explained productive thought in terms of synthetic insight and meaningful versus rote learning (47). Szekley went a step further by suggesting that the 'very reorganization of knowledge is retrospective in character' (48) On further analysis, it appears that the concept of productive thought is more basic than the concept of insight In fact, the concept of insight can be easily hooked to productive thought for the 'pleasant Gestalt Journey' begins when one moves ahead on the basis of incomplete information, with or without 'aha' experience on the way.

Insight. It is one of the main contributions of Gestalt psychology to 'problems of learning; indentification and characterization of insightful behaviour and insightful transposition'. It is interesting to point out that Kohler attributed this concept of insight to animals on the basis of experiments carried out on chimpanzees during his imprisonment on the island of Tenerilic during the first world war (36). He found that, unlike a rat, chimpanzee is capable of using tools which is not an innate ability. He does it because he 'discovers them as a result of successive restructurizations of its perceptions' to meet the requirements of the problem in which meaningful errors are partial insights on way to the complete solution of the problem. He thus rejected trial & error learning as propounded by Thorndike and in its place, 'paid attention to the immediacy of insightful solution' whose characteristics according to E. A. Lunzer are :

1. Suddenness of solution.
2. Immediacy and smoothness after solution.
3. Ability to repeat solution without error on successive presentation of original problems.
4. Ability to transpose the solution to situations exhibiting the same relational or structural features, but in a different context (49).

Where as Kohler showed this phenomenon in chimpanzees, Wertheimer, the father of Gestalt Pschology, demonstrated it in children who brought out successfully the structural features of the problematic situations based upon figures of equivalent areas after having undergone a few appropriate experiences but, at the same time, had not learnt Euclid (42). The opponents of this term, on the other hand, have characterized it as 'mystic, mysterious, anti-scientific and accidental' (40). It is so because according to them, it is not possible to predict the moment of prediction. Consequently, according to E. A. Peel, this term has itself demanded a lot of explanation (40). There is, however, agreement that insight occurs when there is integration of experience, a restructuring or seeing of the new relationship to the problem at hand. Provided the intelligent world existed, Duncker tried hard to distinguish between analytic insight and synthetic insight. The former corresponded to the reproductive knowledge and the latter, to the productive knowledge. It is not possible to distinguish between the two solutions on the basis of the above mentioned two sub-concepts because both understanding and inference are present in successful as well as unsuccessful solutions. This difficulty further increases, according to E. A. Peel, when Gestalt psychology does not evaluate productive thought (40). In other words, it is safe to say that insight implies more than aptness of the solution rather than the existence of high I. Q (39). Yerkes, another animal psychologist but not a Gestalt one says, "that the conventional formula for habit formation is incomplete and that the process of trial & error is wholly inadequate as an account of anthropoid adaptations" (39) He has independently determined the characteristics of insight experimentally which are quite comprehensive and throw light on this concept as developed by Gestalt psychologists It appears that the word 'insight' is tied to the changes in the problem situation itself which bring about the experience of insight to the subject. Van de Geer appears to have said a last word on it when he says :

> A shift in meaning is apparent. It meant to indicate a specific inner experience, later it was regarded as a certain kind of behaviour and now it appears to be a sort of psychological principle (40).

In summary, the Gestalt Psychology, according to Irwin Slesnick, visualizes an active role for the learner in his learning process for he is not a passive entity (50). This implication is naturally linked with self-study and self-education, an excellent culminating point for any educational system any where in the world. Secondly, it discourages the acquisition of facts, concepts and principles without understanding, a positive step towards real learning and knowledge. Thirdly, it stresses divergent thinking in the phraseology of Guilford, that is going far beyond the starting point in one's thinking by setting up all sorts of hypotheses (open hypotheses) and testing them against the given data, the demands of the problem or setting up control experiments with a view to exclude irrelevant variables. These new scientific concepts or insights, according to Irwin Slesnick are gained through a 'series of acts of discovery, however small these steps may be.' (50)

2. The Geneva School

Educational ideas like scientific ideas do not develop in vacuum for they have their past in educational principles 'rooted in the wisdom of the ages', dating back to the ancient Greek thinkers like Socrates & Plato. Since then, the ideas of many great thinkers representing different disciplines have been woven into the fabric of current educational philosophy and practice' (51) Piaget drinks heavily from this philosophical spring and even pays back his ancestral debt abundantly in his life time to the moderns and the futurists for it is impossible to imagine today any study on cognition without reference to his work He presents some sort of thought provoking synthesis of various theories. In his thinking, he has been influenced by Plato's rationalistic tradition, Kant's doctrine of mental categories, Bergson's notion of perceptual change, work of Gestalt psychologists, use of logic for interpretation of thinking (classes, relations, grouping, reversible and equilibrium) and several individual personalities past & present of his country. A few mention are : Calvin, Rousseau, Pestalozzi, Claparede, Binswanger, Bleuler, Rorschach, Meili, Jung and Sechehaye (51). On the top of it, his own subject : Biology has coloured his entire work when he stated :

> Development is continuous not only with the individual but throughout all evolutionary levels. From the biological to the social to the intellectual level, the unity of nature is preserved. The functioning of the loveliest mollusk is based on the same fundamental processes as that of an Einstein (52).

So the contribution of Piaget and his co-workers is monumental. This is despite the fact that his work did not evoke much interest for long. One of the reasons for this poor appreciation was that Piaget is and has been a difficult author to read and understand. But the last twelve years have brought a complete reversal in researcher's attitude toward Piaget. The reason for this is that much of recent research has been geared to verify and test Piaget's basic ideas. Now, according to J. G. Wallace, he can be 'fairly said to bestride the field of contemporary ontogenetic studies like a colossus' (53). Piaget chooses problems for investigation from the area of cognition without considering at the same time any other outside variables like intelligence, socio-economic status, rural and urban differences, personality traits and even motivation. He takes each piece and interprets it from all possible viewpoints (including historical and philosophical) and then gives his own view point. And in this process, he discards all the alternative interpretations considered earlier. It hardly matters for him even if he has to go a long way, according to J. H. Flavell, in explaining his viewpoint even at the cost of limited data collected empirically for the purpose (54).

Piaget acknowledges his debt to Gestalt Psychology for his thinking. A mention has already been made that Gestalt psychology is itself quite rich in ideas for teaching science effectively. But Piaget goes a step further when he says that his scheme are 'more dynamic and modifiable structural units than are the Gestalts' (52, 54). They are characterized by mobility, transposability, generalizability, elasticity, self-modilfiability to fit new data, built-in activity; and lastly, they undergo evolution through corrective contacts. Inferior schemata then become superior ones which are, comparatively speaking, more adequate to reality adaptation. There is no place of insight because the complex schemata arise or evolve from the simpler ones already formed. To put in simple words, unlike a Gestalt, schema has a past history (continuity) which has its own laws of development. It may be therefore inferred from the above, that Piaget does not reject Gestalt psychology in toto but on the other hand, he makes it more mobile and consequently replaces its 'priority with a genetic relativity' (54).

Method of Procedure. Piaget does not use standardized procedures (perception excluded). He chooses methods and techniques refectively for effective exploration relative to the phenomenon under study. He develops his own concepts which are at times misunderstood, misquoted and found to suffer not only from defects but also he is found to change depending upon the period of his work. Difficulties of the readers increase when he does not at all explain his concepts sufficiently well but takes them for granted in his abstract reasoning. At the same time, while sticking to his field, he evaluates critically the findings of others and accepts criticism in turn (49, 54).

Piaget's approach is elastic and flexible. His method is clinical which demands both 'imagination and critcal sense' for a great care is taken in not imposing the experimenter's point of view on the child. Further, Piaget is able to establish a very good rapport with his subjects, In one of his experiments, he proceeded somewhat is follows :—

Piaget : What am I doing ?
Pupil : You are clapping.
Piaget : What am I doing ?
Pupil : You are slapping (55)

Then Piaget presents the problem. He thus succeeds very well in giving us the inside view of what happens when children think. He does this by observing his subjects in informal situations, that is, under natural conditions, questioning them verbally about their every day concepts around the natural phenomena; and investigates their thinking through his highly ingenious experimental materials and physical experiments. He then classifies their responses into stages; and discusses the main distinguishing features of each stage; and how it is linked with both its predecessor and successor stages. He also reports analysis of frequencies of responses and dispersion by ages. He then links these stages to his highly mathematical and abstract logical models. He hardly computes the conventional sort of statistical measures. He hardly uses tests of significance. This naturally publicizes a false impression that Piaget does not have any grounding in statistics and mathematics. To such critics, he has given one apt reply ;

> The object of these studies, initially, was not to establish a scale of develoment and to obtain precise determinations of age as regards stages. It was a question of trying to

> understand the intellectual mechanism used in the solution of problems and of determining the mechanism of reasoning For that we used a method, which is not standdrized, a clinical method, a method of free conversation with the child........ That is why, personally I am always very suspicious of statistics on our results. Not that I dislike statistics; I worked on biometrics enthusiastically when I was a zoologist, but to make statistical tables on children when each was questioned differently appears to me very much open to criticism as regards the results of the dispersion (56).

He has his own reasons for selecting and developing these unconventional techniques. One should not miss the point that Piaget aims at investigating and finding out as much as he can (may it be at its worst considered a sort of exploration) successive cognitive structures in the whole process of ontogenetic development among normal children Therefore, researchers on Piaget have simply to learn to live with them (techniques) for the essence of his critical methods is to 'separate the wheat from the tares and to keep every answer in its mental context, the context may be one of reflection or of spontaneous belief, of play, or of prattle, or of effort and interest, or of fatigue' (57).

It is just recently that Piaget has expounded his eclectic methods of research and theory construction. In these, he employs two essential approaches which have much in common with those applied to nuclear sciences. These are a detailed analysis, in order, of an investigation based upon cause and-effect constituting a net-work characterized by hierarchical relationships and combined connections and the consequent 'analysis of implications by considering both the field as a whole and the co-ordination of its parts, in mathematics, this is comparable to the group, and in logic, to the propositional operation.' Empirical investigations and the inductive mode of reasoning are akin to the first approach, while reasoning by logic and constructing hypotheses by deduction is similar to be second (59). Piaget believes and stresses that symbolic logic like statistical techniques is a productive research tool in psychology as well. One of his colleagues, Inhelder says :

> The use of such tools in no way implies that the psychologist has succumbed to logicism, that is, has decided in advance that the real thought of the child should conform to the laws which govern logical and mathematical structures. Only the facts can decide whether or not it does so conform........These models represent the ideal system of all possible operations, while actual thought makes but one choice amongst them More than twenty years of research have shown that cognitive development approximate these models without attaining them completely (59).

Psycho-Logic Just as mathematical physics helps the physicist to interpret experimental findings in physics, similarly, Piaget constructs his own logic to investigate and interpret intellectual operations. For the last thirty years or so, Piaget has used successfully the various techniques of symbolic logic for uncovering the intellectual behaviour of young children. It will not be out of place to mention here that Piaget is not the first to recognize the importance of logic to test inferences based upon observation. He got this idea from the studies of Kulpe and his students at the Wurzburg school in Germany. Their studies indicated the accessory role of images (not essential as associationists would imply), possibility of reporting the intellectual feelings and attitudes and thought consisting of anticipatory schemata, intention, rules and relationships Apart from borrowing models such as those of Klein and Bourbaki from modern mathematics, Piaget himself has developled one of his own called 'groupements' which are comparable to semi lattices (59). Inhelder has suggested the use of another weaker model which makes use of Boolean algebra. The adequacy of these logicalmodels has been questioned by many crltics like Issac (1951), Parsons (1960), Braine ((1962) and even Bruner (eqilibrium) as a transition rule'. Lovell's remarks that Piaget would have produced a different child, had he had no training in Biology; and certain branches of mathematics had not developed as much as we find them developed in our times (60) It is quite probable then that he may not have produced any child at all as our knowledge is as best as the prevailing conditions allow. And as Wallace says, 'his early training in Zoology, together with his increasing interest in recent years in symbolic logic and the mathematics of groups and sets, have clearly influenced his account of the genetic structures of the child's minds' (53). To conclude with Bruner, there appears to be a potential dynamism in Piaget's system which could diminish some of its angularities. He says;

> ....What is plain is that the adolescent differs from from the child not simply in that he uses a propositional calculus that deals with possibilities rather than mereiy with actualities, but rather that he is forced to deal with possibility by the nature of tasks that he undertakes and by the nature of the unfolding and development of his drives and the social connections required for fulfilling them. It is not an equilibrium which keeps him back

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in this concrete operational stage and not a new equilibrium that brings him forward It is the vicissitude of coping with demands-internal and external. The growing enterprise, that is, an adolescent is now operating on a different programme. Logical strutures develop and support the new forms of commerce with the world. It is just as plainly the case that the preoperational child, protected by parents, need not manipulate the world of objects unassisted until the pressure for independence is placed upon him at which time concrete operations emerge. So the concretely operational child need not manipulate the world of potentiality (save on the fantasy level) until the pressure is put on him, at which point propositionalism begins to mark his thinking. It is no surprise, then, that children of intellectually under-privileged families or of manual workers tend to be less challenged in terms of a sense of possibilities and do not develop what we commonly speak of as an abstract gift (61).

Through the use of his symbolic logic, Piaget is able to discuss the properties of thinking (processes) at various age-levels in terms of what operations children within the age group are capable and incapable of performing He gives reasons why a particular problem (say Shobha is fairer than Rukmani and Shobha is darker than Shubha, who is the darkest of the three ?) cannot be solved by the children within the age group 7-11 years. He said that the thinking of the children is concrete and so they cannot react to the absent situation Logical operations available to them are not sufficiently generalized : and consequetly they can tackle only those problems which are presented to them concretely. To put it in other words, they have not yet evolved a corresponding cognitive structure. When this cognitive structure is present, children try hard to tackle the problem systematically. Trial and error is gradually reduced to the minimum.

Concept of Operations. Prof. Bridgman in U. S. A. was the first to champion that operationalism provides a real meeting ground for psychology and logic As is known, operations play an important part in logic which is based on an abstract algebra and is made up of symbolic manipulations. Here, operations are considered real psychological activities on which our whole effective knowledge is based. Piaget has therefore attempted to develop a psychological theory of operations which links psychology to logic. Roughly speaking, operation is a means for 'mentally transforming data about the real world', so that they can be later on organized and used selectively in problem solving. Operation is internalized and reversible and thus distinguishes itself from a simple action or goal directed behaviour. Consider Piaget's definition of operations :

> Psychologically, operations are actions which are internalizable, reversible, and co-ordinated into system characterised by laws which apply to the system as a whole. They are actions since they are carried out on objects before being performed on symbols. They are internalizable, since they can also be carried out in thought without losing their original character of actions. They are reversible as against simple actions which are irreversible. In this way, the operation of combining can be inverted immediately into the operation of dissociation ... Finally, since operations do not exist in isolation, they are connected in the form of structured wholes (62).

These operations evolve gradually and one can distinguish four main stages in their development, these being the Sensori Motor, Preoperational, Concrete and Formal which cover period from birth to maturity (59).

Basic Ideas. It is difficult to summarize the basic ideas of Jean Piaget for he and his coworkers have contributed immensely to the whole field of psychology; perception, reasoning, intelligence, dreams, moral development, space, time, play, thinking from early childhood to late adolescence and other varied problem areas. It is interesting to note that he has devised experiments with in a highly theoretical, abstract and imaginative frame of reference which have won world wide fame; and are admired highly by researchers on cognitive development with little concern to its theoretical frame. In this context, even Flavell, the best American Publicity Officer, Piaget so far has, is no exception. It is then least surprising that he evokes extreme comments on his work. James J. Gallagher has attempted the following five major themes like conceptual schemes in science running through Piaget's work on the 'development of intelligence as part of the more general process of biological development'. These are:—

(a) Continuous and progressive changes take place in the structures of behaviour and thought in the developing child.

(b) Successive structures made their appearance in a fixed order.

(c) The nature of accommodation (adaptive change to outer circumstances) suggests that the rate of development is, to a considerable degree, a function of the child's encounters with his environment.

(d) Thought processes are conceived to originate through a process of internalizing actions. Intelligence increases as thought processes are loosened from their bases in perception and action & thereby become reversible, transitive, associative and so on

(e) A close relationship exists between thought processes and properties of logic (63).

Thses are very broad as well as grand hypotheses Let us, therefore, consider some of the basic ideas of Piaget with special reference to the teaching and learning of science

(A) There is a constant interaction between the organism and the environment. It is out of this encounter that the intellectual structures are born. Piaget, introduces two basic invariants of functioning, namely, organization and adaptation which are not only inseparable from each other but also are 'two complementary processes of a single mechanism, the first being the internal aspect of the cycle of which the adaptation constitutes the external aspect' (64). This dual functional invariant of organization and adaptation is expressed by the 'accord of thought with things and the accord of thought with itself' (64). In other words, thought adapts itself to things and gets organized to structure things in turn (64). In case of adaptation, there are two interrelated components, namely, assimilation and accommodation. These are two fundamental processes, the former refers to the absorption and integration of new experiences with the existing schemata and the latter refers to the modification of schemata as the result of the new experiences. It may be mentioned here that adaptation is a unitary event and so assimilation and accommodation are merely abstract concepts drawn from this unitary reality which are insparable, indissociable and simultaneous as they operate in a living cognition—'intellectual acts always presuppose each in some measure'. This is something like the concept of 'epignesis', a term borrowed from zoology where the 'function remains the same and the structure changes' (64). While expounding Piaget's basic ideas, Maier says :

> ....Experiences are taken in only as far as the individual himself can preserve and consolidate them in terms of his own subjective experience. Thus, the individual experiences an event as he conceives it. Accommodation is directly converse to assimilation, and represents the impact of the actual environment. To accommodate is to conceive and to incorporate the environmental experience as it truly is. For instance, a loud noise of a door falling shut unexpectedly as assimilated according to its impact upon the individual hearing it; the nature of the noise experienced is determined by the way the individual interprets it. However, the individual also, in varying degees, adapts to the noise for what it actually reppresented, that is, he accommodates to the experience. Thus, both processes always act together. They are interlocked and simultaneously involve conflicting forces between opposite poles; that is, assimilation is always balanced by the force of accommodation, while accommodation is possible only with the function of assimilation. An environmental object is never experienced unless it has a personal, assimilative impact. Piaget stresses that an object can never exist unto itself, it always involves assimilation and accommodation on the part of the experincer. To repeat, processes of both assimilation and accommodation provide complementary, but opposing pulls. A pull to think to feel and to act as previously experienced is

> challenged by a pull to think, to feel, and to act according to the realistic demands of the new situation. Although Piaget's theory is built upon these biological models of homestasis, he warns us as recently as 1953, "We describe behaviour in physiologic or behaviouristic terms. We describe in toto, but we do not know the underlying processes (59).

Flavell further elucidathes :

> In summary, the functional charcteristics of the assimilatory and accomodatory mechanisms are such that the possibility of cognitive change is insured, but the magnitude of any given change is always limited. The organism adapts repeatedly, and each adaptation necessarily paves the way for its successor. Structures are not infinitely modifiable, however, and not everything which is potentially assimilable can in fact be assimilated by organism A at point X in his development. On the contrary, the subiect can incorporate only those components of reality which its on going structure can assimilated without drastic change (66).

Lastly, in this interaction, it is not possible to find the proportionate contribution either of environment or that of organism to the total development. While surveying the evidence for and against the predetermined development, Hunt supports the view that 'analysis of variance model in understanding this mutual interaction is meaningless' (67)

(B) It will not be inappropriate, if we elucidate some of his ideas with the help of Kelvin scale, which is usually mentioned in physics textbooks (65). This is an open-ended scale in which both the highest and lowest temperatures are left unfixed. It is quite difficult to place a restriction on

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the highest temperature, that is, maximally possible and in regard to the other, scientists get into difficulties when they try hard to obtain the lowest temperature (absolute zero) in the laboratory Except these two limitations, this scale is quite useful to the physicists It is possible to visualize the same the organism and the environment out of which intellectual structures evolve. The beginng of this mutual interaction is difficult to fix due to our inadequate knowledge on the beginning of life and its mysterious reproduction; and added to this is the past history of mankind itself. Similarly difficulties arise when we attempt to fix the other end of the scale, the main difficulty being the very evolutionary nature of the knowledge itself accelerated in our times with time dimensions held in posterity. Piaget then attempts in a highly imaginative way how scientific and mathematical concepts develop on this continum. The main features of this scale are now mentioned below:—

(a) When taken in isolation, it is independent of heredity or individual experience. It depends upon both for only then the human mind is able to create new and newer novelties.

(b) On this scale, there are four main stages covering the approximate periods of 0-2 years, 2-7 years, 7-11 years and 11-15 years called the sensorimotor development stage, preoperational stage, concrete stage and the formal stage. Each stage grows horizontally as well as vertically.

(c) Each stage takes time to form and attain equilibrium. Each stage thus formed and attained is incorporated into the succeeding stage. Thus the succeeding stage incorporates the gains of the preceding stage These stages follow each other in a fixed order for the majority of the normal pupils.

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The specified age ranges can vary from culture to culture Thus, there is no rigidity regarding the ranges. Further, it has been seen by Inhelder on the basis of longitudinal studies that intellectual development appears to be slightly accelerated.

(d) Individual differences at a particular stage are disregarded and similarly the specific differences arising due to the specific situations or experiences are disregarded but Piaget concerns himself with the sequence of development of child's thought. Majority of the children pass these stages invariably.

(e) Piaget describes cognitive development in terms of stages, which as such do not clarify anything except logical steps obtained on a particular problematic situation. Piaget goes ahead and investigates further the structure of these concepts (stages) with the help of symbolic logic. It is this work which he substantiates mathematically that gives his work a superb distinction.

(f) With the help of his symbolic logic, he distinguishes among the availability of various logical operations at various age levels. In fact, he pinpoints the strengths and weaknesses of the thinking processes at various age levels and appears to give convincing reasons why the children behave as they do in his experimental tasks. These findings, he generalizes for all children in his highly abstract theoretical frame of reference which is deeply rooted in epistemology. Some of the distinctions stage-wise are :

(i) At the first stage, child lives in his own practical world and he explores various possibilities for his activities. He does not develop self-knowledge and

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self-consciousness about himself. He lacks language and therefore mainly performs overt activities.

(ii) At the second stage, his thinking is governed by the perceptual considerations of the situations. He makes the judgement as he sees the situation. He cannot resolve his conflicting statements.

(iii) All verbal thought is not formal. It may have in it a situation which is in fact concrete. So a formal problem may be solved concretely.

(iv) At the third stage, the subject is tied to the concrete situation or the empirical data. He critizes data and brings extraneous considerations into the problem situation. He understands the content of the problem but fails to appreciate the form of the argument. At the fourth stage, on the other hand, possibility dominates and reality becomes secondary.

(v) Combinativity, reversibility, associativity and identity, etc , available at the concrete stage are shown to be generalized at the formal stage. This explains the emergence of operational schemata like combinatorial, proportional, mechanical equilibria, correlations and probabilities, etc., at the beginning of the fourth stage

Piaget formulates the properties of these thinking processes available both at the concrete stage and the formal stage in such a way as to include both, that is, their 'mobile equilibrium and their ontogenetic formation'.

(g) It is then easy to see the point that all thought is not formal. It may have in it a situation which is in fact concrete. So a formal problem may be solved conceretely.

(h) Piaget analyses thought activities (interiorization of activities) in terms of groups or systems of operations which are relational and possess the following attributes :

a. Composition : Any two operations can be combined to produce a new operation.

b. Reversibility (inversion) : Two operations combine which can be separated again. One can return to the starting point.

c. Associativity : The same operation may be obtained by combining individual operations in different ways.

d. Identity : Combining an operation with its inverse which annuls it.

e. Tautology : It has a special meaning here. Repeating a logical operation only gives repetition or tautology : $Z + Z = Z$ because Z is Z (68).

The above are simple structures (which Piaget calls Elementary Groupements) which are available to the children at the concrete stage. These are, definitely, limited in scope when compared to lattices or to the groups characterizing propositional operations or the operations of classes and relations in their most general form, for example, Boolean Algebra. These have not yet acquired a complete combinatorial character. This in fact evolves at the formal stage and is called the groupement of the second order which is more comprehensible and general and corresponds to later mental structures. To put in simple words, there is a higher degree of reversibility at the formal stage as compared to the concrete stage. Negation (inversion) and reciprocity, the two forms of reversibility, get united at the formal stage in a complete operational system which was not the case earlier. At the same time, they also 'correspond to the model of co-ordinated transformations which are fundamental in thought'. They are 'the operation (identity), its inverse (negation), the reciprocal of the original operation and its inverse (reciprocity) and finally the negation of this reciprocal (correlate)'. Piaget then says :

> ....the construction of propositional operation is accompanied by a series of changes in the subject's capacity to perform operations. The different schemata which he acquires are shown to imply not merely isolated propositital operations, but the structured wholes themselves (the lattice and group INRC) which the propositional operations exemplify. The structured whole is considered as the form of equilibrium of fundamental psychological importance, which is why the logical (algebraic) analysis or such structures gives the psychologist an indispensable instrument of explanation and prediction (69).

It is no wonder then that the children at the formal stage are in a position to obtain experimental proofs, find methods of discovery and develop insight into the nature of proof. They acquire operational abilties (towards the end of this stage) which make possible the undertaking of first class constuctive activities in the development of scientific and mathematical knowledge.

Lastly, the process does not stop here. It continues still further. An equilibrium at a much higher level is obtained (say in case of a mature scientist) which has a link with its predecessor stage. The scale thus tends to be open-ended for the simple reason that the human mind, according to Piaget, goes on creating exciting novelties over the years (56).

The Elucidation of Stages. Let us now refer to the formal period which begins at about 11 years, reaches equilibrium at about fifteen years and finally leads on to adult logic. In this period, they learn to handle increasingly more and more complex logical operations which belong to the calculus of operations. They have the potentiality to perform all those logical operations which are employed by the research scientists, mathematicians, philosophers, historians and even literary critics in their works. To concretize, the adolescent pupils develop the ability to reason by hypotheses based in a logic of all possible combinations, they can deduce their implications, test and verify them. They do not criticize data but appear to accept the hypothetical data even though it may be wrong (suppose the donkey has two horns!) Their thinking is no longer tied to the real (concrete) situation. They imagine and consider all sorts of hypotheses and possibilities. Reality which dominated thinking at the concrete stage is now subordinated to possibility at the formal stage. Further, they test their hypothoses by setting up control experiments and even they go to the extent of finding empirical and mathematical proofs for their observations. One sees at this stage, the emerging of systematic approach where there was earlier, largely, speaking, a cognitive random behaviour. This is so because at this stage, they seriously look into contradictions, and flaws in reasoning and successfully tackle the whole proplematic situation by considering even its basic premises, if judged necessary. The reason for this is that 'there is a new means of generlization and differentiation especially applicable to the eventual integration hitherto unintegrated and undifferentiated structured whole.' Assimilation and accommodation obtain a comparatively higher equilibrium in this period by integrating into unconscious and spontaneously carried out processes of human functioning (69).

The construction of propositions is not the only distinguishing characteristic of this period. New operational schemata (apparently unrelated to each other at the beginning) appear at about 11 +. These operational schemata are : Combinatorial operations in general (combinations, permutations, aggregations); proportion (large number of different kinds of experiments dealing with motion, geometrical relations, probabilities as a function of the law of large numbers, and weight and distance relationships on the two arms of a balance); mechanical equilibrium and others relating to probabilities, correlation and multiplicative compensations. According to Piaget, the gains of this formal period are :

> This fourth period therefore includes two important acquisitions. First, the logic of propositions, which is both a formal structure holding independently of content and a general structure coordinating the various logical operations into a single system. Secondly, a series of operational schemata which have no apparent connection with each other nor with the logic of propositions.

> Justifies the following conclusion : the construction of propositional operations is accompanied by a series of changes in the subject's capacity to perform operations. The different schemata which he acquires are shown to imply not merely isolated propositional operations, but the structured wholes themselves (the lattice and the

> group INRC) which the propositional operations exemplify. The structured whole, considered as the form of equilibrium of the subject's operational behaviour, is therefore of fundamental psychological importance, which is why the logical (algebraic) analysis of such structures give the psychologist an indispensable instrument of explanation and prediction (71)

It is quite possible for the adolescent pupil to discover a few physical laws, for example, law of Inertia himself unaided. Why ? Because earlier, the small child has 'touched, smelt, felt, dug, and climbed'. Now he is building up on this experience by 'pouring, testing, and experimenting' with a view to find sense in the world around him through self discovery (52). This shows that at this stage, new thinking skills begin to appear for he is beginning to commit himself to possibilities rather than to realities. He does not now hesitate to invert reality and possibilities. He can separate himself from the problematic situation and thus have a look at the problem at a distance. To illustrate the above mentioned example on the law of Inertia, he rolls balls of different sizes on a smooth surface. He finds that, whatever may be the smoothness of the surface, each ball stops after some time or over a certain distance. His reason now will not be the force applied to the ball but actually the resistance offered by the surface over which the ball rolls. It is a new variable for the nature of the surface is a factor which is outside of the following variables, namely, (i) the force with which the ball is thrown, (ii) the size of the ball and (iii) the nature of the ball. This is not true only for the law of Inertia. Other physical principles and laws not yet taught at school can also be discovered by the adolescent pupils of average intelligence, some examples being the Laws of Reflection, Archimedes' Principle, Real Depth divided by Apparent Depth equal to Refractive Index, law of Lever and F x D = 100 when focal length is expressed in cms. and D in dioptres (70, 72). They can deduce the consequences of their tentative statements, or trials for testing and verification.

There is a distinct difference between the concrete and the formal stage. At the former stage, all intellectual efforts expanded and intensified on a horizontal plane. Thinking was tied to the concrete situation and was verified even tested within the context of the experimental situation. But, at adolescence, thinking goes beyond the immediate present and attempts are made by the adolescent pupils to establish as many vertical relationships ap possible Notions, ideas and concepts are formed which belong to the present and future. All sorts of hypotheses and possibilities are considered and their implications deduced and tested for relevance or irrelevance. Minute details are not at all ignored. At about the end of this period, the adolescent pupils manifest maturity of cognitive thought for they can use symbols in their operational thinking. In short, they think by applying symbols of thinking or to put in other words, they develop concept of concepts, a sort of second and third order reflection. While rolling balls on an inclined plane, B. Inhelder noticed a progressive change in their attitudes toward the problem solving task which became gradually objective with age. To illustrate, five to seven year olds failed to record the experiments, to reproduce them and to manifest the objective attitudes. They were, in fact, overwhelmed by the situation for they were only interested that they could do to set the balls in motion. Seven to eleven year olds comparatively showed a more objective attitude for they made measurements and comparisons. Even then, they failed to discover the underlying principle. But for the adolescent pupils, the very problematic situation itself provoked them to think and 'attempt at deduction and verification of hypotheses'. Nay, it challenged them to interpret facts and thereby interpretations themselves became an integral part of the intellectual reconstruction. Here, E. M. Churchill then quotes Isaac Nathan who has explored at depth the educational implications of Piaget's theory :

> There are certain basic concepts which pervade and largely control the whole structure of our ordinary adult thought. Chief among these are the notions of speech and time, reality and all causation; number, order, measure, shape and size; motion, speed, force and energy and the ideas of the fundamental logical relations, like those of whole and part, classes, class-hierarchies and their members, and implication. Most of course, would not be able, and would not feel called upon to try to formulate these concepts in all of us, and function in a highly organized and structured way and it is they that provide the coherent framework of our normal thought world through which we order all the succession of impressions, happenings and experiences which flow in upon us.
>
> Children pick up most of these terms, or words connected with them, quite soon and learn to use them in the right situation. This leads to assume, very naturally, that they have the corresponding ideas, at least, in a simple and elementary form. But, here according to Piaget's findings, we are in the main quite wrong.
>
> Thus we end up with a tremendous contrast, above all in the early years of the child, between the onward show of his use of language and the inward reality of the

> actual level of organization and cohesion of his thought. The basic organizing concepts are to all appearance not there yet, and thus have not yet done their work. Hence, beneath the surface, the world of flux to which all Piaget's experiments with children of four to six so elequently testify. Towards seven to eight, as we have seen, the contrast lessens; the organizing concepts are starting to take shape and their work begins to show. Yet it is only at eleven to fourteen that, in the average child, the contrast really disappears. The inward psychological reality joins up with the facade and Piaget's soundings bring out everywhere, just the same kind of responses as any of us adults might give. The child now lives in the same functional thought world as we do (74).

Nathan Isaac then asks: in the light of the above, what is the real status of the so-called progressive education from the nursery education upwards ? Can teacher intervene effectively when intellectual development is an inward affair ? Does it mean that the progressive should emphasize and concentrate on the social, aesthetic or the dramatic aspect of the child's personality ? Piaget admits that these conditions of communal life are quite conducive to the intellectual development. These disturbing questions perforce arise if we accept Piaget's findings in toto. But the facts, on the other side, are also too real and massive and can't be ignored altogether. A necessity therefore arises, to correct or supplement these facts in a comprehensive psychological frame of reference, which may give us rich educational harvest. to quote Hyde :

> There is scope for all, the clinician can study the abnormal functioning of the structure, the educationist the effects of training on its growth, the sociologist, the

effects of environment and others, modifications duet o individual differences. The body of knowledge about children that may eventually result from his work, directly or indirectly is incaluclable (75).

3. Accelerated Learning

It is characteristic of our times that as soon as we understand a process we ask ourselves the question whether we can accelerate that process or not. We do not have a definite answer to this question. However, let us consider here the views of some well known psychologists

(a) **Vygotsky' View.** Piaget leaves us wondering about the educational implications of his work. Vygotsky goes a step further by saying somewhat as follows :

According to him, 'instruction precedes development' (76). He, therefore, analyses intellectual development as a function of instruction explicitly. For him, concepts do not exist in isolation like 'peas in a bag'. Each concept is a 'measure of generality' and they interact with each other. Each concept fits in a certain hierarchy where higher concepts throw light on lower concepts, for example, algebraic concepts throw light on arithmetic concepts. Further, he distinguishes between two types of concepts, namely, everyday concepts (spontaneous concepts) and scientific concepts (non-spontaneous). They develop in opposite directions but it is the instruction which is the main source of child's ideas; which corrects, informs and develops his knowledge. Instruction is not something external but is seen to be integrated closely with development. So planned instruction can accelerate mental development (cognitive functions). We should then aim at the 'ripening of such functions'. Piaget and Vygotsky along with the concept of 'productive thought' thrown in from Gestalt psychology it appears, present an integrated viewpoint to the teachers for teaching science effectively (70).

(b) **Z P. Diene's View** His work is on the concepts of abstraction and generalization but it is with this limitation that he has studied the attainment of specific mathematical concepts in depth. He then in his work distinguishes between the constructive thinker and the analytic thinker. The former takes an overall view of the goal, works intuitively towards it, does not concern himself with the details in the beginning but may attend to them later on. Such children, according to him, manifest constructive thought and are at the concrete stage of their mental development. On the other hand, the analytic thinker progresses towards the goal (which is undefined in the beginning) consciously step by step as demanded by the 'logical requirements within the system'. Children at the formal stage of development exhibit analytic thinking. The emergence of the analytic thought becomes highly probable when constructive thought has already been well developed. There may be certain cases when poor constructive thinkers may manifest analytic thinking. In that case, one can be pretty sure that they have manifested 'shadow actions without any logical significance' in the absence of any (developed) insight into the logical sequence of various events. He then emphasizes that majority of children need a lot of constructive activities before we can expect them to develop analytic understanding. He has investigated and illustrated his ideas with the help of his specially constructed (for the purpose) multibase arithmetic base and algebraic experiences material. He has then formulated four principles of conceptual learning, these being the dynamic principles, the perceptual variability principle, the mathematical variability principle and the constructivity principle. Our gains will be immense if we classify the whole science syllabus (also true of some other school subjects) at these four levels in the form of learning situations to be gradually presented at various age levels. Accelerated scientific and mathematical thinking may then result (77).

(c) Advances in knowledge take place when assumptions underlying thought processes (as understood) are questioned For example, J. S Bruner, Benjamin Bloom and J. McV Hunt believe :

> That an individual's achievement in life depends very largely on what he has been helped to learn before the age of four, for that is when human intelligence grows most rapidly and the roots of intellectual curiosity are laid. They also believe that millions of children are being irreparably damaged because they do not learn enough during this crucial period. The result of an unplanned intellectual died in the early years—for middle class children—may be a loss of brilliance, a blunted and less interesting life, smaller contribution to society. But for the children of poverty, the consequence is always a disaster – a preordained failure in school and adult life (78).

Convinced by the above statement, two psychologists (they appear to be mad !) Bereiter and Engelmann at the Institute for Research on Exceptional Children of the University of Illinois in Urbana are 'operating an intellectual presure cooker'. They have rejected the usual philosophy considered progressive in the play-oriented nursery schools. On the other hand, they 'concentrate fiercely on a few areas and drill the children like Marines for two hours a day'. Consider their approach in a mathematics lesson with four pupils, two boys and two girls :

> It is time to think about ....work ! he began fairly shouting. Are you ready tough for stuff ? On the blackboard, he wrote $8+3=?$. Immediately the children started to roar, 'Eight plus zero equals eight, eight plus one equals nine, eight plus two equals ten, eight plus theree equals eleven and the sums like $15+a=18$ and $7-b=2$ It looks like algebra for the four-year-olds (78).

Very soon, these disadvantaged four-year-olds are able to 'unpack' or extract meanings from the statement. They can speak in sentences. The students get an experience of success because the educational programme (in a very narrow sense) is geared to their capacities and capabilities. Teachers have faith and confidence in their children and, in turn, children have faith and confidence in their teachers and these arise in the very process of work from deep involvement and commitment in a common task. Regarding this project, J. McV. Hunt says :

> There is evidence of more changes in Bereiter's school than in any other I have seen. When he set up his class last year, the children were tested 'under-age-three' on the Illinois Test of Psycholinguistic Abilities. They did not talk to each other at all except in single words and grunts. In each of two-three-month periods of this school, they gained about one year of psycholinguistic ability on the tests (78).

(d) In England, Wall has drawn pointedly the attention of the teachers to 'distinguish between the logical structure of a subject, process or technique, and the psychological mode in which it is taught.' If a teacher presents a notion, operation or technique concretely and is found of interest and immediate value by the child, it is quite possible for the child to acquire it at an earlier age than hither-to considered than 'if it is unrelated to his interests and presented in a symbolic, abstract or generalized way' (79). The reason for this is that even content remaining more or less the same, the psychological processses involved are different (79).

Hyram has pointed out that children's school work improved when they were trained in logical operations (80). Morf has also found that children were induced to learn 'certain operations of class inclusions by employing a method involving direct training on the operations of logical multiplication' (81) But investigations of Lovell and Ogilvie and Dowedell do not favour the acceleration of concept formation when training in logical operations is given to the students (81). We can, however, safely conclude that a very potential and fruitful area of research awaits invasion by the educational psychologists, and teachers in particulars.

(e) J. G. Wallace in his recent book on Stages and Transition in conceptual Development, has also referred at depth to the problems underlying such studies, the problems being philosophical, psychological and technical (85). There are problems for the practitioners as well when not only subnormal but also normal pupils fail to form Schemata which they ought to have in their normal course of development. For example, Elkind found that about 53 per cent of the American adolescents in the age group 12-18 year olds failed to conserve volume (83). Hence, there is a scope for improvement here because, when left to themselves, they cannot perform this job themselves efficiently. "The end in view is, then, the production of adults possessing a comprehensive range of cognitive tools, as Flavell and Wohlwill have put it 'not at first but at last, not the fustest but with the mostest' (84). In such studies, what would be our gains for children ? According to Wholwill, these may be 'in a particular response, a group of particular responses, a more general notion' similar to operation as defined by Piaget (84). Secondly, is the process entirely new in contrast to the process normally developing process ? Examining the problem from varied view points, J. G. Wallace summarizes the situations as follows :

> '....... a definitive answer to the question of the nature of the relationship between the processes evoked by training sequences and those which figure in 'normal' development is still a considerable way off. Taken in conjunction with the only slightly more clear evidence on the question of the authenticity of the changes in performance produced by training, this assessment supports the conclusion that the case against the educational utility of acceleration studies remains to be proved. In the interim, their potential practical contribution in the search for methods sufficient to produce the attainment of particular landmarks in cognitive development appeals to make the continuation of acceleration studies worthwhile. The balance of the evidence suggests that future studies conform to certain guidelines if they are to make the maximum contribution possible on both the empirical and the theoretical planes. The acceleration treatments used should be based on task or process analyses at the level of detail exemplfied in the work of Gagne' (1968) or Klahr & Wallace (1970). They

> should, also include an extended series of relevant learning experiences involving the use of a wide veriety of materials and presented in a sufficiently non-directive fashion to allow children to employ their own preferred modes of mediation.... ...
>
> It would be a rash reviewer who would suggest that solutions to these problems lie just round the corner. The road to the cognitive researcher's 'hell is paved with such optimistic prognoses. Sufficient be it to say that the present tendency to tackle complex issues with complex instruments is sufficiently encouraging to tempt the writer to conclude with the assertion that in 1971 the outlook for research on conceptualization and in the wider area of cognitive development appears to be considerably brighter than in 1963 (85).

Lastly, it may be mentioned that research in this area is just coming up. It is, therefore, not possible to answer the question whether accelerated thinking can result or not. Over generalization in this area may be quite dangerous. But it appears that accelerated thinking under certain conditions and within certain elastic limits is possible. It is not impossible to teach atomic and set theories in the primary school by the new enthusiasts. But they are mistaken if they think that change of content or down grading of content in itself is a complete reform. Substantial and complete reforms result only when relevant material drawn from the significant areas of human living as the subject of study itself is used to develop and improve thinking through imaginative approaches. Here, well-structured experiences need to be designed, imparted and then evaluated.

Problem at the focus of attention, reasonable freedom including flexible time-tabling and permissive and responsive environment go a long way in imparting inquiry skills to the pupils. Under these conditions, children accept the teacher's word after full consideration of the relevant data including the necessary experimentation In this triple process of concept formation, concept attainment and problem solving, incomplete hypotheses expand to complete hypotheses by appropriate rectifications where one strategy, if it does not work, leads to another strategy. Children then take into consideration the significant aspects (elements) of the problem. During attack on the problem, they develop their own insights and gather and develop new information, knowledge and skills. The consequent knowledge obtained through self-involvement in the problematic situation is not only meaningful but also very stable in character. It is no wonder then that cognitive structures are modified materially and are available for subsequent use. This availability is not as direct as one may get the impression because our environment under natural (or even otherwise) conditions creates expectancies and violates them off and on; and this exerts an educative influence. This is a more difficult job for the teacher to accomplish in comparison to the teaching of the few isolated junks of advanced knowledge in the school syllabus. The teacher's difficulties increase manifold if he looks to the educational psychologists for help and guidance. This is, atleast, true in this country (17).

SURVEY OF RELATED STUDIES ON PROBLEM SOLVING IN SCIENCE

Chapter III

Survey of Related Studies on Problem Solving in Science

Status of Research ;

About sixteen years ago, D. Wheeler said, "It is strange that at a time when there has been a rapidly increasing need to select and educate those who are specially suited for training in scientific work, the psychological study of the processes underlying scientific reasoning has been so widely neglected" (86). About eleven years ago, it was alleged that research in American Science education is inadequate for it suffers from limited imagination, evaluating outgoing practice instead of 'functioning as beacon and too many no significant differences studies' making suspect both the tools or the hypotheses under study (87). The same tradition appears to continue when Wayne W. Welch, while reviewing research in science education at the secondary level for the biennium 1968-69, says :

> ....It is a distillation and characterisation of the research efforts of science educators. Specific references have been pointed out in the various sections and several documents have been used to illustrate the points. Much of the work appears fragmented and uninspiring. Perhaps this is due to the fact that motivation for most of the work is completing some external requirement, a

thesis or funding report, rather than generating knowledge about the educational process. This hypothesis is supported in some sense by the quality of work that appears in a few places that have on going research projects associated with them. There is hope for educational research only when experienced researchers are able to devote the majority of their time to seeking the answers to important questions. At present, we are far from that goal (88).

At home, the situation in regard to Research in Science Education is quite depressing because Research Career in Science Education is the least rewarding. In fact, it is a research desert characterized by the lack of personnel, problems and publicity. It is recently that the National Council of Educational Research and Training and the All India Science Teachers Association have done a bit in this direction. In a very recent publication on a Survey of Research in Education, D.B. Desai and Sunirmal Roy deplore the quality and quantity of researches conducted in the area of curriculum, methods and textbooks for 'most of them have centered round the surface problems, and that too, covering the middle and secondary school stages only' (89) Out of ten studies reported four are in science, five in mathematics and one in home science. They then add :

> Research in curriculum and instruction deserves more attention than it has received so far. Even in the advanced countries of the world. it is criticized as being inadequate, out moded and not properly designed to meet the needs of modern society. Against the back ground of striking curricular developments in those

> countries, the school curriculum in India is narrowly conceived largely out of date.
>
> ....The studies on teaching methods hardly made any significant impact. Most of them compared some sort of practical biased approach of instruction with the traditional 'chalk and talk' method and branded the former as progressive or effective without caring to go a bit deep into the fact as to why, in what way or how it was so. In a word, no approach was made towards a consistent theory of teaching. Another most significant fact about these studies under review was that quite a large number of them was not grounded on sound methodology. The limited scope of their sampling restricted, to a great extent the validity of their generalizations (89).

On reflection, these critical remarks apply to the frame of reference rather than to individual studies which when seen cumulatively do strike a note of optimism. This view point is confirmed by the studies summarized below.

2 Varied Studies Surveyed

G. Stanley Hall studied the contents of Children's minds and there by emphasized the importance of primary or first hand experinece rather than bookish knowledge. He further stated a well known educational principle (known to unknown) "Concepts which are most common in a given locality are the earliest acquired, less frequent ones come later, no one child has all the misconceptions recorded, none is free from them....The fact that children see objects a hundred times without acquiring consciousness of them suggest that we ueed to converse with children about common things" (91). Keen studied children's reasoning and found that children under study has 'weak urge for experimental verification'. Children are sure to develop illogical concepts if teacher does not take sufficient care while introducing new experiences to them (91). Deutsche examined the nature and development of causal reasoning a phase of children's thinking in the context of the Geneva School with the aid of the problems with and without experiments. She noticed a gradual growth of reasoning in contrast to stagewise growth as suggested by Piaget. Secondly, she did not find the detailed classification of reasoning into seventeen types useful as found by Piaget. Thirdly, school experience explained specific responses to the specific questions which she suggested had direct and indirect implications for teaching and training children (91) Oakes investigeted qualitatively children's explanations of natural phenomena and concluded that all age groups regardless of mental ability and grade gave all types of answers. Further, adult groups did not follow any definite procedure while explaining unfamiliar phenomena. Thirdly, he did not find a definite stage in children's thinking characteristic of a given age (92). He thus confirmed the earlier findings of Deutsche, Keen, Hazlitt, Johnson and Josey, Susan Issac and Haung, who had found that both American and Chinese children 'gave naturalistic factual and logical explanations of phenomena' (93). W. H. King, while exploring the development of scientific concepts of children (N=1235 between 5 to 12 years) with the aid of seventy questions suitably classified into five categories : 'Length, weight, time, direction; volume and weight; mainly mechanical principles, lever, wheels, living things; seasons and shadows concluded;

(a) Children at all ages gave all sorts of responses.

(b) Like Oakes, no stages in causal reasoning as propounded by Piaget were noticed. Response appeared to be, largely speaking, the function of question rather than solely the function of age.

(c) Some children showed difficulty in verbalizing their concepts which in fact they had understood as earlier reported by D. H. Russell. He then added :
Perhaps there is a need about eight or nine years of age for the harnesssing of this experience so that knowledge can be obtained by other, though not necessarily more formal, means. These experiments have shown that children of primary school age have accumulated a knowledge of scientific facts and that this knowledge increases with age in some cases very steadily. Some of the answers had to be obtained by reasoning on the basis of past experience and these also showed steady increase with age upto 8 or 9 years. Beyond that, a-priori reasoning was not sufficient & adult guidance and explanation seemed essential, at least, in concepts relating to estimation of length, direction, weight and volume (94).

Banks studied the development of children's thought (11 + to 13 +) with the help of demonstration experiments which illustrated certain scientific principles. The subjects were low I Q. pupils studing in a secondary Modern School in England. His main aim was to find out the relationship, if any between the kind of answer given and the age and I. Q. of the individual pupil. Deutsche's classification (materialistic and non-materialsistic) was used

His results showed that these children can explain experiments which are performed before them inteligently. Secondly, age and science teaching had a greater effect on the ability to draw conclusions than did I. Q. but those with high I. Q. did better in the number of explanations in the higher categories (95). Using auto-instructional device, Keisler and McNeil found that contrary to the view of Piaget, six and seven year old children can give acceptable scientific explanations for physical events. They can not only learn abstract principles but also with some practice, would probaly show more facile expression and more accurate use of scientific language in the solution of new problems' (96) Navarra investigated the conceptual development of his own son (very young and above average in innate ability) over a period of two years This study is rich in detail and the observations are first hand. Moreover the observations were based upon informal conversations. The most important findings of his study were :

(a) The development is gradual and its most interesting and characterististic feature is the long period necessary for integration during which the child gathers together and inter-prets for himself the experience encountered in highly diverse situations, e. g., seeing water in its different forms and distinguishing it from steam or distinguishing steam from smoke.

(b) In this development, there appeared the evidence of 'gradual differentiation and development of expectancies, testing ideas, analysing experience, finding positive and negative instances and maintenance of an inquiring attitude' etc. Even the earlier insignificant details and concerns were seen to have initiated growth later on or constituted a progression of events in the total frame of reference (97) The study, however, lacked comparison with the findings of Piaget.

In an observational and analytical study on thought processes of school children and college students, Buswell found 'variety rather than similarity in the sequence of thinking'; and failure to solve the problem at racts all sorts of hypotheses. Benjamin Burrack concluded that even undergraduate students failed to distinguish among different methods of attack on problems involving induction, deduction and geometrical analysis. On puzzle type situations, Heidbreder found that reactions and sensitivity to problems increased with age; a gradual change with age from a more subjective attitude to a more objective attitude and characteristic and individual reactions to the problems apart from the fact that the 'general pattern of the solution became more general or definite but new rigidity set as the ago increased' (98). Mumford found that training experience and practice influence thinking only if it is regarded as a mental skill based upon innate capacity. She suggested that educative experience is a vital experience in the life of an individual and needs to be handled with great care so as to develop self confidence and persistence in the face of 'disappointments and threats of failure during problem solving' (99) Bloom and Broader showed that the successful problem solvers differed from the unsuccessful ones in respect of the following variables : 'ability to use rather than the possession of the total fund of information; extent of thought brought forward on a problem and attitude towards reasoning, confidence in the problem and the introduction of extraneous considerations into the problem situations'' (100). Employing the combined use of experimental statistical and introspective procedures Wheeler concluded that children possess logical reasoning at much earlier age than hitherto assumed by teachers; and 'most of the elementary schemata necessarily for valid reasoning are already within the capacity' of the seven year old children (86). Here, one should not dismiss straight away the very dependence of young children on first hand experience.

In other experimental study of experimental problem solving by Durkin which resembled Heidbreder and Mumford's work, it was aimed to examine the effect of the nature of the problem solving process and the appropriateness of the concepts used to describe the behaviour involved. Subjects were asked to talk aloud as they proceeded ahead with a well organized series of two dimensional puzzle situations. The problem solving behaviour evoked by these puzzles could be photographed. At the end of the experiment, each subject was asked to retrace his whole situation from the beginning to the end. Any point of interest was was discussed. The main findings of this study indicated.

(i) Problem solving behaviour in human adults is never at random inspite of the fact that they may not see the relevance of their moves as judged by the goal to be attained,

(ii) Three types of solutions were distinguished, namely. trial and error, sudden reorganization and gradual analysis which could be termed as three distinct forms of thinking. Certain transitional cases showed that such distinction was difficult to maintain showing thereby the existence of continuum

(iii) Observation, recall, seeing relations, attention to goal, manipulation and inference were the processes present in all the three forms of thinking (101).

In conclusion, it is not known at what age formal reasoning begins. This age is found to be quite variable due to cultural differences and individual differences within the same culture. The most important question still left unexamined is this : whether each individual passes through these stages in succession as enunciated by Piaget and Inhelder or he is able to pick up the higher stage without having developed in him the preceding stage. In other words, this means : Is skipping stages in individual development possible ? If this is found to be so, we have yet to know the relationship between the size of the jump and the various conditions both within the individual and outside, that make such jumps possible. In a restricted sense, the area of concept formation is also equally full of problems; possession; and availability of concepts verbally (Smoke); Catergorizing and conceptualizing (J. S. Bruner, Goodnow & Austin); relationship between intelligence and types of Piagetian concepts developed (Beard); Varied behaviour in structuring problems right from childhood to late adolescence (Buswell); lack of clarity and distinction among various methods of attack; clear formulation of the problem, preliminary survey of all aspects of the presented material, analysis into major variables, locating the crucial aspects of the problem, application of the past experience, varied trials, control elimination of the sources of error and visualization (Benjamin Burrack)! distinction among different types of solutions; trial & error, sudden reorganization and gradual analysis (Durkin); role of general or specific experience of concept formation; & problem solving (Maier); and characteristic differences in successful and unsuccessful problem solvers.

"Scientific thinking is largely a matter of good thinking habits," says E A. Peel (102). It is in the light of this definition that we will survey some more studies on problem solving in general as well as on science teaching relating to laboratory work, scientific inquiry and problem solving in science. All science teachers, largely speaking, try hard to develop good thinking habits among their pupils.

(1) In 1925, Carpenter investigated the comparative effectiveness of laboratory and demonstration methods over 1,000 subjects and concluded that "pupils equally succeed well if success is measured by instruments which measure the same abilities as are measured by these tests, namely, specific information and ability to think in terms of chemistry." In 1958 Brandwein, Blackwood and Watson analysed the tests of Carpenter and commented that both the groups could succeed equally well independent of the above two methods on the basis of textbook knowledge alone (103)

(2) In 1928, Horton attempted to probe further but confirmed the above mentioned finding of Carpenter. His experimental groups were given Individual laboratory work without direction, individual laboratory work with generalized direction, individual laboratory work with a manual of direction and demonstration by the teacher. His conclusion was "no reliable results appear in the testing by the ordinary written examination neither by the regent nor by the school test." With the laboratory tests (non written), he found the following differences in ability i. e. to set up and manipulate apparatus and to solve problems (or work on projects) in the laboratory. In 1958, Frings and Hichar confirmed Horton's findings (104).

(3) Atkin studied the role of accuracy of response, type of response (appeal to authority, use of observation, appeal

to experimental and original explanation etc) in formulating and suggesting tests for hypotheses in Elementary School Science Learning Experience. His main finding was that "pupils are more active, successful when they select and work on their problems" (105).

(4) In an experimental study, Lahti ascertained the effectiveness of laboratory in developing student ability to use the scientific method to evaluate the effectiveness of the teaching methods and to design and construct laboratory experiments, and instruments. His evidence supported the following statement of Kruglak;

> There is hardly a better method of teaching scientific method than the one which places the student in the same position as the research scientist, where he faces the same difficulties, commits the same mistakes, suffers the same accidents and explores the same blind alleys (106).

(5) Extending over a period of seven years, Kruglak has investigated some behaviour objectives for laboratory instruction, experimental outcomes of laboratory instruction, achievement of physics students with and without laboratory work, the measurement of laboratory achievement; the effect of high school physics and college laboratory instruction on achievement in college physics and evaluating laboratory work by the use of objective tests etc. He confirmed the findings of Carpenter and Horton (106). Brandwein, Watson and Blackwood have emphasized the importance of laboratory work in their studies. Children then learn to work carefully, accurately, predict from first principles and select, design, search and improve laboratory equipment and techniques. At about the same time, Brown

also made a similar type of investigation but without using any statistical niceties and concluded that "students who had physics laboratory work in high school were inept at naming or identifying the function of equipment which they were known to have handled in the high school' (107).

(6) Muthulingam also attempted to assess the scientific thinking ability, attainment in science, attitude toward science and interest in the scientific field of boys and girls studying physical sciences in the fifth year of the secondary school in England and Ceylon and contribution of the factors in the schools, such as, the type of science course, the laboratory facilities and methods of teaching science, etc. A battery of tests was constructed to measure the various aspects of scientific thinking-definition, problematic situation, reasoning, application of principles and ability to analyse and observe etc. Regarding application of principles, he says, "Results of the sub-test on the application of principles in England seem to be in favour of a method of teaching, emphasizing theory and restricted laboratory facilities." He further adds, "There is, however, evidence for better power of observation by the provision of good laboratory facilities and practical method of teaching (108).

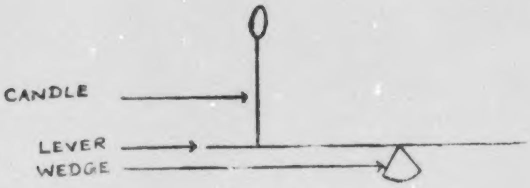
(7) Charren George investigated the effect of open ended experiments on the achievement of certain objectives of science teaching. Six M. C. A. (Manufacturing Chemists Association) experiments and six comparable traditional laboratory exercises were chosen for the experimental and the control group. The M. C. A. experiments involved certain elements of the scientific method like seeking solution to the problem, to make predictions and to set up apparatus and control experiments Attempt was also made to test some attributes of critical thinking like ability to interpret

data and to associate with the nature of proof etc. The study was carried over 268 students. His main conclusions indicated that open ended experiments like the M. C A. do succeed to develop scientific attitudes, skills and motivation. Secondly, both open and traditional exercises do result in significant learning. Thirdly, there is no conclusive evidence that a laboratory approach has led to improved critical thinking in chemistry (109).

(8) Butt has studied the degree to which children conceptualize from science experiences. He confronted 24 pupils from the fourth, fifth and sixth grades with science experiences in order to see concept development arising out of this new experience. Four other questions were also examined : relationship between concept development and chronological age, intelligence and attainment in science, influence of a given concept in the development of a different concept and recognition of a given concept in a new situation or experience. The concepts under study related to displacement, inertia, action, reaction and depth pressure relationship. The experiments were done under three different conditions, namely experience phase, question phase and a manipulation phase. The findings of this study do not support the popular assertion that meaningful concepts will definitely emerge when a child is provided with proper experience or environment and the free opportunity to experience certain perceptions (110). In the opinion of this writer, it would have been better if Butt had considered the causes that contributed to this failure by analysing their wrong responses and interpreting them.

(9) Szekely attempted to investigate 'knowledge as the starting point of independent thinking', by presenting the same problem in three different forms. Different subjects

were used for three forms of the same problem. Consider the following problem.



(Fig ii)

Showing Szekely's application problem

(a) The candle is lighted and the subject has to explain why the level falls down.

(b) The same arrangement. The subject is asked what would happen if the candle were lighted.

(c) In this case, there is opportunity to find solution through free experimentation (111).

Szekely believed and, therefore, hypothesized that knowledge can be investigated in its' function of end result, starting point and medium of learning and thinking'. He found that knowledge gets reorganized in the process of thinking which starts from the object of thought. Secondly, the three different forms of the situations or presentations of the same problem differ only in the extent of difficulty of restructurization which, in its turn, depends not only upon the piece of knowledge (needed to solve the problem) but also upon the total situation. In addition, Szekely carried out quite a few studies on productive processes in learning and thinking; and then posed the following problem to himself yet to be solved since it was posed about twenty five years ago :

It is well known that different individuals who have the same knowledge show great differences in the original application of this knowledge. Does the applicability of the knowledge depend solely upon the differences in individual endowment or is it also dependent upon the method of learning and teaching ? Is it possible to increase the productive applicability of the knowledge that is the capacity for creative thinking by the improvement of the methods of learning ? (111)

Two methods of learning were compared, namely, modern method and the traditional method. As learning materials, a few laws of mechanics served which were to be applied to a relative different task, namely, the problem of two spheres. The main findings of this study indicated :

(a) If judged by the frequency of successful solutions alone, the modern method is superior to the traditional method even when "endowment is taken into consideration." But Maltzman, Eisman and Brooks (1956) have failed to duplicate this finding. According to them, "Either method, or a combination of the methods, produced more solutions than control group with no training but there were no significant differences among the three experimental groups" (111)

(b) Productive knowledge evoked in the process of problem solving and the verbal reproducibility of definitions are mutually exclusive of each other. This means that the rote memorization of definition or facts will not guarantee the solution of the problem (111).

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(c) Improvement of the learning method improves comprehension of the learning material which fosters independent productive thinking later on (111).

It is necessary to replicate this type of study by drawing concepts from the new curricular programmes developed in the wake of Revolution in Science Teaching in relation to several outside variables over a very large sample.

(10) In his investigation of the thought-processes of a group of fourteen year olds during the solution of a scientific problem, Kyle showed, "that pupils tend to progress by hind sight." "They tend to jump to the end of certain phases and then to return to fill in the blanks ..." "A problem only becomes real for person when he has some rudimentary foresight of a tentative solution ..." He further showed that 'a doing group went further towards a solution than a thinking group.' This is so because a doing group can rectify its mistakes in the process of experimentation (112).

(11) At the higher age group, Whellock attempted to inquire "into Howfar scientific method is gained from Science Education." His subjects were sixth-form pupils and military college students After partialling out differences due to intelligence, he showed a significant relationship between the scores on method and attitude and the scientific background (113),

(12) Mealings investigated certain aspects of problem solving in science among secondary school children above 100 in number varying in intelligence. Most of the problems were original ones and in fact seem to meet the requirements of the complex human tasks as needed in such type of studies. The general aim of his investigation was to

understand from first principles, the solving of scientific problems by the adolescent pupils in a normal school-setting. More specifically, his aims were to investigate the relationship between the problem solving ability (at the formal level) and the mental age and to consider the influence of personal attributes on the problem solving ability. Sex differences were also considered Two series of four experiments in each were administered among two groups of children in turn. A case study approach was employed and the responses were recorded verbatim, then arranged and analysed to see the course of thought on each problem. The main results of his study indicated that problem solving in science is more related to intelligence than to chronological age. (This is understandable). There appears to be a minimum mental age of 13 years before a child can reason formally about a problem and there is a time lag between the empirical solution. and the formal solution. Taking an overall picture, Mealings says we should not expect children to solve abstract and theoretical problems in science until they reach a mental age of 16 plus. It is also possible, at this stage, to undertake topics requiring an understanding of matrical proportions, i.e. Boyle's Law, Ohm's law and theoretical problems concerning moments and specific heat in physics and the laws of chemical combination in chemistry (114).

(13) Neal attempted to ascertain specific procedures that aid children in developing the ability to use methods of scientific inquiry in grades (I to VI) in the laboratory school of Colorado. The author attempted to determine the elements of problems solving to develop and select illustrative teaching techniques, which promote growth in the ability to use the methods of scientific inquiry, to judge

the effectiveness of the various teaching techniques and lastly, to observe and describe the kind of covert behaviour characterized as the method of scientific inquiry Identifying and stating problems, selecting pertinent and adequate data, formulating and evaluating hypotheses and seeing relation were the various methods of scientific inquiry selected. He then concluded that children not only developed scientific interest, confidence and responsibility by the practice of scientific method but were also capable of developing abilities in practising the above mentioned elements of the scientific method (115).

Partly influenced by activity and core patterns of curriculum (including basic notions of community school in the U S. A., the U. S S R., and Phillipines) Willard J. Jacobson in a paper entitled 'Science Education and the Development of Abilities to cope with Problematic Life Situations' developed a working frame of reference in which SHOULD rather than HOW questions receive first priority. His main assumption is that "We can and should help individuals and groups to develop the abilities to recognize and cope with problematic life situations of which they are a past". He then sought 'operational answers to the question of how these abilities to cope with problematic situations, could be developed'. For the development of these abilities, he suggested the following three phases. Use of proposals based upon past experience dealing with the development of these abilities through science education; analysis of the whole act of adjusting with the life situation, and consideration of the same in terms of judgements and values. He thus advocated the use of life situations for their consequences can be seen and felt first hand which, the process, will help adolescents master dilemma in their own characteristic ways. To quote Jacobson :

> New relationships are difficult to perceive, and a group may eventually reach a point at which they are stymied. In such situations, it may well be fruitful to have a period of rest from the intesive examination of the problem After a period of time, they will necessarily view the problem from a different point of vantage, and hence, new relationships may appeal The mysterious period of 'incubation' that has been suggested by Helmholtz and Poincare does have this realization. During the period of rest, some of the extraneous material that was, perhaps, blocking their view of the situation may be forgotten. With the elimination of these elements, the discovery of new key element, or the new view from a different vantage point as the result of a passage of time, new and fruitful suggestions are more likely to appear (116).

(14) In a practical piece of research, Fleshner has emphasized the importance of children's everyday experience in teaching abstract concepts in Physics. Researches of N. E. Weaver and E. N Madden have advanced two conditions for success for problem solving, namely, the 'presence of corresponding knowledge' and the 'mastery of research operation'. For example, the concept of weight involves weight for all bodies, earth's pull and force. Open-ended questions were posed to the children. Every child could answer at least a part of the problem. An interesting finding emerged that eighty per cent of the subjects were of the firm opinion that 'bodies which they had not measured had no weights'. Thus there is direct educational implication of the above : the definition (weight here) should not be taught and stressed too much in science teaching but on

other hand, it should stem from their floating ideas (living practice) when a given theme is introduced in the classroom (Goriachkin, 117).

(15) Stendler is of the opinion that superior intelligence does not imply 'superior performance both in linguistic and scientific fields". She emphasizes the importance of well-structured childhood experiences which facilitate learning later on. She explores the following hypothesis: "that certain kinds of childhood experiences structures an individual's perceptions of the physical world, that the percepts are stored as information cell assemblies in the cortex and that the neural reservoir facilities the learning of concepts in the physical science". Then she discusses the nature of experiences that might contribute to the building of such a neural reservoir. She then suggests the use of teaching models that will help the elementary school pupils develop functional understanding and skills needed for the physical science (118).

(16) N. Vaidya investigated problem solving in science among certain groups of adolescent pupils (15+). The results of the study indicated that contrary to Piaget's view, the adolescent pupils do not hesitate to criticize data. Secondly, there is a general tendency among adolescent pupils to set up hypotheses which they test against the given data. Thirdly, a poor problem solver appears to stick to one idea at a time stubbornly and, later on, ceases to think of alternative ideas Consequently, he gives up the problem in disgust. When problems were analysed for their mathematical structure through the technique of factor analysis. The following four factors appeared, namely, Attainment, Practical, Interest and Adjustment. The outstanding conclusion of his study was that Problem Solving processes derived from

different problems as well as analysed differently (using Guttman Scale) confirm and support Piaget in principle (119) But, at the same time, it may be added that the study lacked hypotheses as well as suitable study population (N=60; and N=31).

(17) Vijaya Lakshmi investigated the thought processes of backward children (12+) with special reference to the Schemata of Combinatorial Grouping. She also examined continuities and discontinuities in their thinking with the help of scaleogram of problem-solving processes. The coefficient of fluctuation came out to be 49.7%, which was on the high side. But when the various responses or thought processes were appropriately grouped, the coefficient of fluctuation came out to be 5.6 percent, that is within acceptable limits. This showed that appropriately grouped processes of thought within a restricted age-range constitute a Guttman Scale (120). Using Piaget type tasks in arithmetic, K. R. Sayal, concluded that items relating to the algebraic symbols and the scheme of proportion are hardly mastered by the 11 years old children. Secondly, they are capable of showing more thinking than they are deemed to have as judged by class teachers on their achievement in mathematics. Thirdly, the top group was influenced more by the form rather than the content of the problems in comparison to the bottom group when attempt is made intentionally to invite wrong answers, a finding consistent with Piaget's ideas. Then he added :

> Through questionnaire technique, it is not possible to find exactly the reasons for the errors incidentally committed on the problems, From indirect evidence, the reasons appeared to be the following poor mathematical vocabulary, failure to add, subtract, multiply and

divide exactly, underdevelopment of the scheme of proportion in particular, failure to generalize their thinking to algebraic symbols and, possibly, the use of more mechanical ways of thinking than intelligent understanding of the problem (121).

(18) Robert S. Tannenbaum used an entirley different approach, while developing the Test of Science Processes, namely, Observing, Comparing, Classifying, Quantifying, Experimenting, Inferring and Predicting. This study is unique in the sense that very little is known about the emerging of these processes at various age levels. When the test is looked at depth, it does not use problems involving a continuous chain of reasoning, all of the test items being, of course, process based and of the multiple choice variety. Moreover, the various processes in relation to known tests useful for interpretation of the same processes lack factorial evidence. Still, the author at least appears to have achieved the main purpose of the instrument : 'Measurement of Progress towards Behavioural Objectives' (121). But it is not known in what order and at what ages the various processes are mastered by pupils. In contrast to this study, R. M. Misra, using Piaget type tasks, investigated the role of hypotheses formation in solving problems inhering a continuous chain of reasoning among X grade science students. The main findings of his study indicated :

(a) A given problem is solved over a wide I. Q. range. A low I Q. pupil may solve the problem successfully where as a high I. Q. pupil may fail on it

(b) There is no significant difference between the top and the bottom group in regard to the average number of hypotheses set up. It is of interest to point out that bottom group identified two other variables, namely, tension and elasticity of the thread which were not suggested by any member of the top group.

(c) When the mathematical structure of the problems used was analysed through factor analysis, the following five factors appeared : General Adjustment, Seeing the problem as a whole; Formulating Hypotheses; Interest in Generating Difficult Problems (whose answers they do not know, that is, posing such questions on cow and cycle); and newness of the problem.

(d) There is a general tendency among adolescent pupils to set up all sorts of hypotheses but, at the same time, they have aw-fully failed to test the various hypotheses. The main findings here is that their minds have not become trully experimental 123).

(19) This finding receives support from a paper on Promoting Intellectual Development Through Science Teaching by John W. Renner & Anton E. Lawson Using two Piaget tasks on the conservation of Volume and the Exclusion of Irrelevant Variables, they found that 'out of the population from which physics students are drawn, not many are formal operational' as shown in the table below :

TABLE 2 1

Showing the number of adolescent pupils grade-wise and sex-wise possessing ability to conserve volume as well as to exclude variables.

S.No.	Grade	Population		Conservation of volume	Exclusion
1.	XI	Male =	45	26	23
	N=99	Female =	54	19	14
	XII	Male =	50	34	20
	N=97	Female =	47	8	16

When the same two problems were administered on 185 college freshmen, only 133 and 77 could show successfully the conservation of volume and exclusion of variables behaviours. This shows that even the majority of College freshmen have not moved deeply into the formal operational stage of thought (124). In another informal study on 11 College freshmen, Sharon Bastian & others, using four Piaget adapted tasks (these were the pendulum, the inclined plane, angle of incidence and reflection and volume) found that 'none of the eleven subjects performed on the formal operational level'. In other words, this meant that they found logical experimentation difficult. Secondly, there did not exist any significant correlation between scores on Piaget tasks and the other outside variables like standard achievement test scores; current grade point average scores; predicted grade average scores; and high school percentiles. Thirdly, scores on Piaget type tasks were least influenced by sex, age, and major area of study. Why ? The reason could be that approach to the courses which they had studied was least inquiry centred (125) John W Renner & Anton E. Lawson remark (in the context of Science Curriculum Improvement Study Project under the guidance of Professor Robert Karplus) :

> Our research has shown us that the level of thought of junior high school students and college freshmen can be changed by providing them inquiry centred experiences in science. We believe that the principle reason our research has shown an increase in the thought levels of students is because we accepted that most of them participating experiments were concrete operational. That squarely put upon us the responsibility for providing concrete experiences with the objects and ideas of the

> discipline These students were involved in actually creating some knowledge of their very own. We know that it was the first time some of them had been given that opportunity. We believe that actual involvement with the materials and ideas of science and being allowed to find out something for themselves accounts for movement toward and into formal thought which we found.
>
> ....This teacher is not a teller, he is a director of learning. Traditional teaching methods embrace the notions that (a) teaching of telling, (b) memorization is learning, and (c) being able to repeat something on an examination is evidence of understanding....those points are the antithesis of inquiry....The development of formal thought must become the focus of attention of every teacher in the country...the central role of the school must be to teach children with form not objects - in other words, to move students into the stage of formal operational thought. Science has the structure to enhance greatly the achievements of this objective. We must not blow our chances to make a maximum contribution to education in general and education in science in particular.' Let us establish an environment in our classrooms that encourages and promotes formal thought (124).

It is a grand hypothesis which needs to be tested under as many diverse conditions as feasible. In another interesting study, using the well known pendulum on a very wide age group 10-50 years, Kohlberg and Gilligan reported that a 'large percentage of adolescent population is not formal operational'. The results obtained by them were :

Table 2.2

Showing the percentage of adolescent population able to reason formally in various age groups.

S.No.	Age group in years	Percentage
1.	10-15	45
2.	16-20	53
3.	21-30	65
4.	45-50	57

It appears that adolescents are not making full use of their 'talents and tools'. This percentage being quite high even within the age group 16-20 years (126).

(20) W. F. Archenhold investigated the concept of 'potential, electrostatic and gravitational, including related concepts such as work done and energy' as held by a group of sixth farmers in the age group 16-19 years in the north of England Twenty five tasks were designed which tested their understanding through a series of theoretical and practical situations in the above mentioned areas in physics. These pupils not only exhibited limited understanding but also misunderstandings which, in a way, reflected their difficulties in grasping these concepts at advanced level. When results were factor analysed, using Hotelling method, a strong intellectual/educational component appeared while 'Varimax rotation isolated two factors containing tasks associated with potential and work done respectively (127).

(21) Robert Eugene Norton, attempted to assess Children's Ability to Solve Problems in Science developmentally using a test (T. S. P. Tab Science puzzler) of adolescent pupils studying in grades four to six. He investigated

relationships between problem solving ability in one hand and other variables like previous science knowledge; I. Q.; age and reading ability; and selected cognitive factors of intelligence Main findings of this study indicated :

(i) Problem solving performance is related to previous knowledge, a finding consistent with Wellock on a higher age group.

(ii) Although the selected cognitive factors are not related to total problem solving performance, flexibility and speed of closure and reasoning are related to the problem–solving subtasks, problem orientation, problem solution and data analysis.

(iii) Based on the correlation between problem-solving performance and I. Q , age and reading ability, no evidence was found to support a relationship between problem-solving, I. Q. and reading ability.

(iv) Chronological age appears, to be related to problem solving in certain areas (128).

(22) It is possible to see the same problem in a different context by making use of objective tests in which reliance is placed on the initial answers which are then subjected to advanced statistical analysis. A lead in this direction has been given by STEP (Sequential Tests of Educational Progress) which needs mentioning for its objectives according to the publisher are to measure several skills : picking up the problem, sharp formulation of the problem hypothesizing, designing experiments, interpreting data (also conflicting), developing objective procedures, evaluating evidence critically, using symbols and written materials, and their interpretations. Consider the following problem :

Situation. You are the engineer directing a new dam project on a certain river. You have team of scientists, i. e biologists., chemists, geologists, meterologists, and physicists in assistance on the project You have to locate the dam in the best position and arrange for the hydro-electric power and the irrigation of the surrounding district which is a semi-arid zone region. The water level is to stay 300 feet above the river,

Subject matter area — Geology
Ability — To identify and define a scientific problem.

On the following, the most important problem requiring your attention would be :

(a) To find the point where the river banks come closest together.

(b) To find the point where the largest and deepest lake could be built up behind the dam.

(c) To investigate the characteristics and structure of the rocks underneath the river bed and along the banks.

(d) To determine the least amount of inhabited land that would be flooded (129).

Like line spectrum, children's thinking is tested ability wise but, at the same time, a specific suggestion of value has been made by Gupta in another study when he says :

> It may be possible to conduct researches on the mutual relationship of purely factual and tests requiring the understanding and application, with both types based on identical subject matter. A high correlation may mean that the tests of the latter variety should be preferred because of their desirable influence on teaching and

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learning habits, whereas a low correlation may mean the desirability of both the types with suitable weightings. However caution may have to be exercised in generalizing any relationship discovered in small experiments because there are other variables also, for instance, differences in the teaching practices noticeable in different schools, and so on, which may effect the result to an appreciable extent (130).

Inquiry Training

It is necessary to refer to Inquiry Approach in science teaching in passing. J. J. Schwab has aptly remarked that the 'Problem now facing teacher of science is no reblooming of a perennial' but it is a 'mutant-new in so great a degree as to amount to a difference in kind'. He distinguished two aspects of scientific inquiries, namely, stable and fluid, the latter aspect relating to science in the 'making' in which even the very principles of inquiry remain suspect (131). It is not only that, it is the teacher who talks too much in the classroom but also, it is again he who also asks questions about 97 percent of the time As children move up in the respective higher grades, this very teacher behaviour results in their becoming less empirical. In other words, they, instead of trusting their own concepts, begin to accept external authority in an unreflective manner (132). The Illinois Studies in Inquiry Training Project under the guidance of J. Richard Suchman began in 1957 and identified over the years the following ideal conditions for developing inquiry skills among elementary school children; focus for attention; freedom (external and internal); and responsive environment in the words of O. K. Moore Elementary school children are exposed to discrepant events which by their very nature compel them to analyse, for example, the erratic behaviour of a bimetal blade on heating and cooling. Films were made in quite a few school subjects like physics, biology and economics. They were forced through these episodes containing discrepant events with the aid of yes-no questions to seek their own explanations. Learner is thus enabled to direct and control his own learning. Suchman regarded inquiry as a 'Process of Discovery' comprising the following four phases : searching, data processing, discovery and verification with a view to investigate several causal relations. Using other outside variables including known tests and scores on inquiry and subjecting the data to factor analysis, the following three factors relevant to success in inquiry appeared :

(a) Impulsivity factor : the capacity to leave beyond data to generate abstractions. Zero in on.

(b) Cognitive Control : the ability to handle and manipulate data.

(c) Autonomy. The second is related to this because for if you never leave the data, you will never construct the data (132).

Inquiry into science teaching is a never ending process until the dead hand arrives; and it has to be shown so. Ben Strasser has shifted the focus of inquiry on teachers rather than pupil behaviour, another interesting research question (132). Alphoretta Fish, on the other hand, shifts the same on alternative methods of inquiry, thus giving three different meanings to the term Inquiry (132). Le Von Blazer makes out a strong case for developing inquiry skills as one of the most important outcomes of instruction in biology. He thus supports J. J. Schwab, Anderson and Robert Gagne for it provides opportunities for scientific thinking. Again he quotes Gagne, who sums up various writers on inquiry, ' I judge them to mean, that it is a set of activities characterized by a problem solving approach of which each newly encountered phenomenon becomes a challenge for thinking" (132). John H. Woodburn in Discover and Describe stresses the investigative approach to science teaching by presenting puzzling events or situations to children which intentionally 'offend' their senses The observable cognitive conflicts provide a 'realistic visible format easily communicable between student and teacher' (133). Using programmed materials, Robert M. Olton and his co-workers tried to assess the extent to which 'specified productive thinking abilities, can be taught to elementary school children.' Being a comprehensive project, they raised the following additional questions:—

(a) Are some productive thinking skills more amenable to instruction than others ?

(b) Can productive thinking skills be learned by children of all I. Q. levels ?.

(c) How are productive thinking skills affected by a classroom environment judged to facilitate creative expression ?

The main findings indicated that use of programmed materials "led to an increase in the level of productive thinking in this large and representative group of fifth grade students" (N = 704) at three levels of I. Q. included in the study. However, the extent of generality of training was limited, the main reason being the kind of problems rather than kind of performance measures employed. Secondly, both the experimental and control groups demonstrated on demand simple cognitive skills, training being inessential.

The latter, however, hardly use them in their day to day work. The complex tasks, on the other hand, necessitate the use of advanced skills which were not yet available but could be developed in training sessions. Specifically speaking, contrary to the findings of Covington and Crutchfield (1965), there does occur a gradual increase quantitatively as practice trials training sessions increase. The role of facilitating environment was also found ineffective at the end of the project because the 'treatment was particularly effective with students in non-facilitating environments. The girls were found superior to boys on all types of problems As research problems, they have suggested to re-examine the same problems with which they started by determining the presence or absence of cognitive skills at various age levels, finding skills amenable to practice in contrast to training or instruction and the quality as well as quantity of training sessions (134).

In another restricted study on "Hypotheses Formation can be Taught," Mary Ellen Quinn, using twelve film loops of 12 minutes duration each, the Schumanian way, showed that both urban and suburban children produced statistically significant improvement in ability to hypothesize.' It is of interest to mention that the training comprised better recognition of the problem, distinction between empirical and non empirical based statement, observation of properties or behaviours of objects in the loopfilms, drawing of inferences, determination of empirical relations between observed and inferred variables and experiments for testing hypotheses (135). She thus confirmed the earlier finding of Richard C. Anderson that training sessions did help even the first graders on transfer tasks. These first graders constituting the one top thirds on the California Test of Mental Maturity, however, failed to show superior performance on the pendulum and the chemical problems. Sex also did not play any significant role (136). Through variable teaching techniques, it is possible to teach facts and concepts of astronomy to two groups college freshmen with little effect on the students' understanding about science as measured by TOIS (137) A. Maureen A. Dietz and Kenneth D. George attempted to develop a reliable and valid tool for measuring the problem solving skills of children in grades one, two and three. These were : recognition, understanding of scientific principles necessary for the solution of the problem, collection of data and handling, if-then statements (138). But the study fails to answer the basic question. For example, consider the following two studies as well.

David P. Butts and Howard L. Jones in another earlier study on 'Inquiry Training and problem Solving Skill in Elementary School Children' devloped an inquiry training programme as suggested by Suchman whose outcomes could be measured by an instrument especially developed for this purpose, namely, Tab Inventory of Science Processes (TISP). A child inquiring into a problem shows the following behaviours; searching, processing data, discovering, verifying and applying concepts to new situations. They intended to investigate the effects of training sessions on the problem solving behaviours of children as well as the role of outside variables like intelligence, sex, chronological age and factual knowledge in changed problem solving behaviour consequent of the instruction. They also examined whether inquiry training led to meaningful concept development, using sixth grade students (N = 106) and inquiry sessions extending over three weeks daily, the main finding indicated that when exposed to guidance, there resulted enhanced problem solving behaviour. Secondly, changes in problem solving behaviour were insignificantly related with tested intelligence, chronological age, sex and factual scientific knowledge when compared with the control group, the above mentioned variables did not appear to play significant role while drawing benefit from inquiry training. They then remarked aptly :

> Much discussion has been given to the relationship between meaningful concept development and inquiry. The results of this study do not support the assertion that meaningful concept development results from inquiry training. Children who were successful problem solvers on TISP were not able to apply the concept to a different situation. Why ? Is the application of a concept criterion to a different situation an adeqaute for mean ingful concept development ? Were the situations 'too different' for the child to see the relationship (139) ?

At the same time it is also necessary to determine why a group of children fails to show changes in problem solving behaviour and relate them to their personality makeup. Robert E. Yager and John W. Wick do support that certain phases of pupil outcomes are definitely the result of varied intentional teaching strategies but, at the same time, they provide the following disturbing conclusion that there is no significant difference in the mastery of the major concepts and facts of biology (as measured by the Neslson Biology Test) by the students among the three emphases used by the teachers of the study (140). In his writings, J. S. Bruner has talked of discovery, structure, early readiness and intuitive thinking. He gives a clarion call for discovering imaginative modes of inquiry among children so that each child is 'capable of going beyond the cultural ways of his social world, able to innovate, in however, modest a way,

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so that he can create an interior culture of his own' 'For whatever the art', he says, 'the science, the literature, the history, and geography of a culture, each man must be his own artist, his own scientist, his own historian, his own navigator' (141). He is nearer to Plato as well as to Piaget for his learning by discovery is tied to their theoretical melange—'an environmentally dynamic version of contemporary developmental theory in conjunction with a twentieth century form of classical relationalism' (Lee S. Shulman). B. F. Skinner, Robert M. Gagne 'and David Ausubel take the opposite view (141). Each of them takes a restricted view of learning, at least, at the starting point. A bit later, it becomes a case of learning hierarchies : guided learning, and reception learning While reviewing researches on discovery, Ausubel appears to state the following conclusion, a sort of educational disaster :

(a) That most of the articles most commonly cited in the literature as reporting results supportive of discovery techniques actually report no research findings whatsoever, but consist mainly of theoretical discussion, assertion and conjecture; of descriptions, of existing programmes utilizing discovery methods, and of enthusiastic but wholly subjective testimonials regarding the efficiency of discovery approaches.

(b) That most of the reasonable well-controlled studies report negative findings.

(e) That most studies reporting positive findings fail to control other significant variables or employ questionable technique of statistical analysis. Thus actual examination of the research literature allegedly supportive of learning by discovery reveals

> that valid evidence of this nature is virtually non-existent. It appears that various enthusiasts of the discovery have been supporting each others research by taking in each other's laundry, so to speak, that is, by citing each other's opinions and assertions as evidence and by generalizing widly from equivocal and even negative findings (142).

Instead, to 'provide ideational scaffolding', he gives the concept of Organizers which in their differnt forms try to close the gap between what the pupil knows and what he is expected to know before he can master the task at hand. He thus restores the threatened status of the teacher in his scheme of learning (142). Regarding accelerated learning, it is of interest to refer to the founding of Project : Head Start in U. S. A. in 1965. Engelmann and Bereiter have reported startling successes with their slum children, for example, not only, they can speak complete sentences, solve simple arithmetical problems, read words and learning their spelling but also have registered increase in their intelligence. There are negative reports as well, for example, they are most of the time tense, frightened and respond automatically' (143). Barbara Biber, here, remarks that the method through its effects on attitude and therefore on motivation, becomes a secondary determinant of how far the original learning goal will be realized' (143). Here, neither scrambled textbooks nor the high sounding educational technology like the Computer Assisted Instruction will be of use if used indiscriminately, for it may well kill curiosity, interest and individuality by 'making all men alike and not necessarily alike in nice ways' (143). Piaget is here conservative when he says :

> We know that it takes nine to twelve months before babies develop the notion that object is still there even

when a screen is placed in front of it. Now kittens go through the same stages as children, all the same stages, but they do it in three months so they are six months ahead of babies. Is this an advantage or is not it ? We can certainly see our answer in one sense. The kitten is not going to go much further. The child has taken longer, but he is capable of going further, so it seems to be that the nine months probably were not for nothing. It is probably possible to accelerate, but, maximal accelaration is not desirable. There seems to be an optimal time. What this optimal time is will surely depend upon each individual and on the subject matter. We still need a great deal of research to know what the optimal time would be (144).

It is a million dollar American question, empirical experimental in nature whose research answer will illuminate Piaget's invariant clockwork of the order over the years. According to Lee S. Shulman, we have not yet exhausted fully the various creative approaches leading to the solution of this problem of cognitive acceleration for we have at the moment 'access only to opinions and personal prejudicies' (141).

It is of passing interest to refer to the study on the development of algebraic concepts among pupils studying at the junior secondary stage in relation to outside variables like levels of intelligence, sex and grades by J. N Joshi. He standardized an algebraic concept test in Hindi containing seven categories like generalized numbers, directed number, equations, parentheses, substitutions, exponents and graphs. His findings indicated that all the broad categories except the one on directed number developed from grade to grade. Secondly superior intelligence is necessary for the formation of algebraic concepts. Thirdly, boys have a tendency to excel girls in the understanding of algebraic concepts (145). In another equally interesting and novel study on Analysing test Responses with symbolic Logic, Gary R. Smith attempted to assess pupils' success in understanding certain concepts of light with the help of multiple choice test items. He made detailed as well as distinct element-analysis of question and answer for testing pupil understanding on both. A fortran programme was written which would indicate the network of correct and incorrect responses Twenty deductions were derived from five propositions. This approach has limited utility for difficulties lay in arbitrary allotment of symbols, the very designation of the class, confusion between symbolic proposition and unique statement of item proposition and omnibus nature of the test (146)

3. Overall Evaluation and The Scope of the Problem

After having surveyed the field of human thinking with special reference to reasoning, concept formation, problem solving and school science education, it is now necessary to have another close look at the survey with a view to pose the present problem and state its scope. Science in its forward march does not pose impossible problems. Psychology, in our times, also claims scientific status Therefore, like science, it must also pose its problems in their solvable forms for generating new objective knowledge. It is easier said than done for several variables intervene and, make in turn, the investigation of psychological problem very difficult as is shown by the survey. Still, the findings of the various general as well as specific studies undertakes in different contexts not only within a given paradigm but also across the various ones, when consolidated, indicate :

(a) Thinking is multi-faceted in character. Its investigation, particularly speaking, of higher cognitive processes is considered to be a complex task. In our times, it ought to be the main job of the second psychological revolution to tackle successfully the various attendant problems, however, small they may be (147). The present survey reports several such studies against several theoretical standpoints undertaken with this objective in mind which attempt to make this complex problem a bit more transluscent.

(b) To facilitate this, thinking need no longer remain a 'ghost' like activity. As a first step, it is essential to short-circuit several definitional complexities if any worth-while progress is to made at all. To illustrate, even a restricted field like problem solving has been investigated in the past under different heads. To surmount this problem, thinking in this study is regarded as a skill. Secondly, problem is defined as a task oriented situation having a clear cut solution with a view to facilitate the study of thinking processes.

(c) The survey clearly shows that it is theoretically possible to investigate any cognitive problem relating to any one of the following paradigms . S-R. theories, Gagne's viewpoint, phenomenological theory, factor analytic approach, information processing, accelerated learning, Gestalt psychology and the Geneva school. It is not implied at all that one frame of reference is superior to another for, after all, it is finally a matter of individual choice in which attempt is made to catch the fish rather than seek specialization in the art of angling. This choice, again, is dependent upon the aims and objectives of investigation, the nature of the very investigation, extent of controlled experimentation

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actually available and the physical facilities for carrying it out.

The present study draws its inspiration from Gestalt psychology, Geneva School and the factor analytic approach. Secondly, it goes a bit ahead, for in comparison to other workers in the field, it uses several problems having scientific flavour but, at the same time, each inhering a continuous chain of reasoning. Thirdly, the varied problem solving processes evoked during problem solving, largely speaking possess clear cut solutions which in turn, can be reclassifed or regrouped with definite advance hypotheses in mind. In summary, a promising line of inquiry of this nature is just perceptible in the area of thinking or problem solving The present problem not yet tackled, is one among many, available in this area.

(d) To pinpoint, the present study investigates certain aspects of thinking through the medium of problem solving among science students of adolescent age who were matched on two variables, namely, intelligence as well as socio-economics status. When seen by exclusion, the following problems, of course, important receive little attention in this study :

(i) Problems relating to creativity variables.
(ii) Role of situational variables
(iii) Concept : formation as well as attainment.
(iv) Predictive studies.
(v) Acceleration studies.

(e) In continuation, these problems can't be ignored for a long time the survey clearly makes out a case for investigating some of these general problems urgently A few examples of such problems having some sort of association with our study are cited below : —

(i) At what age do children begin to manifest formal reasoning ? What factors favour its early emergence ? At what age do the adolescent pupils develop firm urge for experimental verification ?

(ii) What variables determine vast individual differnces in thinking ? It is suspected that these variables are : intelligence, individual abilities, personality traits, task characteristics and varied instructional methodology.

(iii) Do sex differences exist in thinking at various age levels ? If so, why ? Are they genetically determined ?

(iv) What exactly is the relationship between concept formation and its application ?

(v) Why children fail to verbalize their concepts when they had, in fact, understood them ? Is a correct test response given over a wide I. Q. range not only within individual grades but also across the various grades ? Up to what extent can a given concept be down graded ? What are the transitory conditions ?

(vi) What is the role of hints and cues in the teaching learning process ? Under what conditions do they really become effective ?

(vii) Does thinking develop in stages ? Do all the children go through the same stages ? Particularly speaking, do the thinking processes develop unidimensionally ? How to test this grand hypothesis ?

(viii) What kinds of thinking processes does the training under experimental conditions generate ? Are they really chips of the same block or different blocks ?

(ix) Under what specific conditions does learning take place maximally ? Alternatively, under what conditions do the acquired concepts really become dispo sable or acquire 'measures of generality' ?

(x) Lastly, what is the relationship between intelligence and the varied Piagetian concepts ?

It is a long shopping list in which problems overlap. The present study, while investigating thinking, takes into account intelligence, grade, adjustment and the immediate test reactions to the problems on presentation.

Concluding Statement

A major shift in thinking is apparent. It converges on specificity in the formulation and reformulation of problems more and more productively in the phraseology of Gestalt psychology. This point of view or approach to the problem facilitates studying experimentally the varied processes of thinking which lead to the development of understanding, generalization, discrimination, concept development and attainment. This initial spin off gain is not easily seized because, as already mentioned, it is easier said than done. The main reason appears to be that the researchers, on the one hand, and the practitioners, on the other hand, both placed in different settings, do not necessarily ask the same question. These split questions are bound to appear in the business of any science, psychology being no exception. It is then not a case of despair, for the solution to the problem then lies in considering the two problems separately as is frequently done in the case of certain anomalies in science. However, when answers to the split questions are mastered successfully, one after another, the whole field over the years becomes quite explosive. The area of creativity is a case in point. Thus are answered the most fundamental questions in science. The basic problem here is to relate the most powerful concepts of science to the intellectual development of children. The psychological structure of any school subject depends upon the answering this basic problem. The present study is an attempt in that direction.

Lastly, whereas the whole area is full of problems, the latter now lie more in the zoo rather than in the jungle. Thanks to the recent research efforts of Ausubel, Bartlett Bruner, Flavell, Gagne, Guilford, Hans Furth, Humphrey, Inhelder, Lovell, Lunzer, Peel, Piaget, Schwab, Skinner, Suchman, Vernon and Wallace, a few among many noted workers in the field, it has become possible to pose specific problems in this area which was however, not the case over twenty five years ago. This survey succinctly tells that psychological concepts do not, develop in a vacuum for children live in environments; physical, mental and social. They learn formally, informally, and equally possess personal knowledge about men and matters. How is then their thinking generalized at various age levels in apparently different psychological constructs ? It is a very basic question yet in search of satisfactory answer. Like the proverbial five blind men, the whole elephant has to be reconstructed bit by bit again and again. Our miserable failure on this front has deprived us of any worth-while psychological structure for any one of the school subjects, at least, in this country (148). Several specific studies are needed whose answers over the years are bound to illumine the very bases of the likely emerging productive frame of reference. The solutions to these problems may not be very far off, yet they also, at the same time, equally lie currently beyond the nose. To conclude on an optimistic note, efforts in this enterprise are going to be more successful than in the past.

At the same time, it is also equally stressed that the whole field of human thinking which is as vast as humanity itself throws up quite a few fundamental problems which are yet to be investigated even partially before we can fully understand the basic assumptions underlying human thought processes. And the latter, in turn, are also open to continual scrutiny.

References

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Chapter-IV

Some Main Investigations Summarized

[Even today, very little work has been done on the formal stage of mental development as enunciated by Piaget. The reason for this is, that it is very difficult to carry out studies using 'Methode Clinique' However, it became possible to carry out a few studies at the R.C.E., Ajmer. Support from ERIC (NCERT, New Delhi) recently helped in the quick crystillization of thought through a series of studies zeroing in on each other which are now mentioned below.]

Study No. I

A Study of Some Aspects of Thinking Among Science Students of Adolescent Age

Introduction

Education for understanding and problem-solving is gradually becoming the chief goal of instruction at school in the wake of revolution in science and technology, all over the world. With a view to achieve the goal, it is necessary to investigate 'pupil thinking'—a term which appears to suffer from multiplicity of meanings according to Bartlett, Peel and Russell. At the beginning of the century, John Dewey suggested that 'thinking' takes place in stages. This led several workers like Bloom, Duncker, Johnson and Mills and Dean to see varied stages in thinking. Whereas it is more difficult to establish stages than to find stages in the solution of any problem involving complex reasoning, at the same time, it is comparatively easier, according to Duncker, to investigate thinking empirically through problems which have clear-cut solutions. In fact there are several problems in the area of thinking which need intensive investigation. The present study, however, investigates some aspects of thinking among science students of adolescent age. The main objectives of this study were :

Objectives

1. To study thinking (problem-solving) processes, evoked by individual problems, each containing a continuous chain of reasoning

2. To study the same processes when appropriately grouped, regardless of the typology of problems.

3. To study errors as they occur in solving these problems.

4. To determine the relationships between scores on thinking and some outside variables: intelligence, sex, various immediate test reactions to the problems on presentation and adjustment.

5. To find out the characteristics of successful and unsuccessful problem-solvers.

6. To analyse the structure of the appropriately grouped processes of thought factorially and interpret them psychologically,

Hypotheses

The following hypotheses were proposed and tested :

1. Problem-solving takes place in stages.

2. The scores on problem-solving are significantly related with the following independent variables: intelligence, sex, immediate test reactions to the problems on presentation and adjustment.

3. The complex problem–solving processes arise from simple problem-solving processes.

4. A given poblem is solved over a wide IQ range.

5 Poor problem-solvers are influenced more by the content rather than the form of the problem.

6. There are significant differences in respect of the variables included in this study.

Procedure

Sample and subjects : A sample of 200 students, 100 boys and 100 girls, ranging from age 10.5 to 11.5 through 14.5 to 15.5 years from Grades VI to X was selected on the basis of intelligence and socio-economic status. Pupils within each sub-sample (20 boys and 20 girls) and across five sub-samples were matched on intelligence and socio-economic status which were measured by the group mental ability test by Jaiota and the socio-economic status scale by Kuppuswamy.

Selection of problems : Seventeen problems containing continuous chain of reasoning were finally included in this study which were administered indivdually in two sessions. These seventeen problems were further analysed in terms of thinking processes necessary to solve these problems which were further reclassified into seventeen schemes of thought : Using constant difference, Using summation, Using proportion, Beaker combination, Using two digits at a time, Using three digits at a time, Using four digits at a time, Generalization to algebraic symbols (summation), Generalization of algebraic symbols (proportion), Stating hypotheses, Testing hypotheses, Stating procedures, Proposing tests, Formulating problematic situations (fluency), Formulating problematic situations (flexibility), Using insight and Failure to grasp the essence of the problem.

In addition to the intelligence test and socio-economic status scale, adjustment inventory as developed by M.S.L. Sexena was used which provided five measures of adjustment, namely, home, health, social, emotional and school. Summated scores on immediate reactions to some of the problems, on presentation were also obtained which related to understanding, felt difficulty, confidence and interest in solving problems

Summary of Findings

Subsidiary findings being numerous, the main findings of this study indicated :

1. Pupils of the lower grades experience difficulty while reading the problem. They also miss the answer spaces. Each one is affected differently over a wide IQ range by the baffling nature of the problem.

2. Except occasional fluctuations, average performance on each problem increases with grade. Mean performance in most of the cases favours boys rather than girls. Boys and girls (or girls and boys) try hard to equalize their performance as they go up the grades.

3. A given problem, part of the problem, or process in that problem is soved successfully or failed over a wide IQ range both within and across the various grades.

4. A given problem is solved in stages. It is posssible to identify stages in the solution of any problem empirically. In continuation, each pupil sees the problem in his own unique way except when problem is solved mechanically,

5. Largely speaking, pupils show gradual mastery in an increasing manner over the various processes, taken individually, as they move into higher grades It is in the closing grades only that they appear to verbalize or state their methods of attack. Here again, the very choice of the problem is the single determining factor.

6. Unexpectedly, pupils commit a large number of errors while solving problems. These errors further increase when they ignore or forget or fail to grasp the main demand or requirement of the problem. Each process of thinking underlying a given problem has attracted, largely speaking,

a large number of errors, sometimes, as many as 49. These errors when committed in small numbers, that is, by less than 15 per cent, of the pupils (N=200) appear, disappear, reappear and sometimes persist across the various grades. Others, which are dominant, that is, shared by more than 15 per cent of the pupils, have a general tendency to decline with age which is an expected finding

7. Over three-fifths of the pupils from Grades VI to VIII are badly affected when a problem involves a sort of reversibility, that is, thinking has to be done in the opposite direction. When it comes to the generalization of arithmetical thinking to algebraic symbols, pupils belonging to Grades VI through IX fail to generalize their thinking to them.

8. When a problem can be solved through two schemes of thought, one inferior and the other superior and if the latter is not well developed, the resort to the former may favour quite a few in solving that problem. In case, these two schemes of thought are absent, there is a little chance for a given hint or illustration necessary in the solution of that problem, to be utilized during problem-solving. This possibly explains why the pupils of Grades VI to VIII have failed in making use of hint or illustration in their problem-solving behaviour.

9. According to Gestalt psychology, the problem is seen as a whole. The present investigation does not support this view. It is only in Grade X that the pupils are in a position to see the digital problem as a whole.

10. Depending upon the nature of the problem, adolescent pupils, contrary to Piaget, are affected to a varying extent by the content of the problem. The overall incidence of content influence in terms of multiplicity of responses declines

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with grade, that is, from 68.46 per cent to 32.92 per cent from Grade VI through X.

11. In their attempts to solve the problem, the adolescent pupils magnify the problem out of its proportion by bringing several extraneous considerntions into the problematic situation which distort its logical solution. In this resulting frame of reference, they carry out astonishingly complicated reasonings. Our experience with these problems showed that attempts were not blind at all despite fact that they continue to rub the problem at the wrong end.

12. Pupils of Grades VI and VII do not possess the scheme of proportion in solving the spring balance problem. Their performance on this problem in the next higher grades is also poor except in Grade X where 75 per cent of the boys and 55 per cent of the girls are in a position to tackle the various aspects of the problem successfully. Further, it is only in Grade IX and X that pupils are in a position to see the weight of the container as detachable from the main demand of the problem. In the lower grades, it is found merged with the demand of the problem itself.

13. Like exhausting combinations or all possibilities majority of the adolescent pupils, when it comes to the, proposing of tests for distinguishing among three rods, do not care to exhaust or propose all the possible tests. If any one of them proposes one test, he considers it unnecessary to propose the second one for the problem if, in the first instance it stands solved. If compelled or placed in a tight situation, he may end up with another, extra test. Unless coaxed still further, there is again hesitation in proposing the third test for the third stick already stands identified by the process of elimination. There is another interesting observation as

well : 7·5 per cent of the pupils most of them from Grades IX ond X, have suggested a 'rusting' test. It means that they can await pronouncement of definitive judgement in their thinking for a couple of days if the nature of experimentation so requires. It is a healthy sign or a creditable achievement on their part that they just considered this test. Lastly, it is 14.5 per cent of the pupils coming from Grades VIII to X who have proposed more than one-third of the total number of proposed tests. It is in these grades only that extent of thought brought into play on this problem has been manifested.

14. In accordance with Piaget's view, adolescent pupils are in a position to set up hypotheses. Among them, only 71 per cent are in a position to set up three or more than three hypotheses. This again further confirms that the adolescent pupils do not imagine all the possibilities in toto. Secondly, whereas adolescent pupils are in a position to set up hypotheses, they also, contrary to Piaget's viewpoint, make comments in the form of arbitrary errors which have nothing to do with the solution of the problem.

15. Barring few fluctuating cases, the ability to test hypotheses does not appear among pupils from Grades VI to VIII. It does not appear among girls of Grade IX but in the next higher grade, they beat boys by 10 per cent. The data indicated that more than 70 per cent pupils of Grade X could not manifest the ability to test hypotheses which means that to that extent the individual minds of given Grade X children have hot yet become experimental. Considering the three study variables in isolation, these were isolated by 13.5 per cent (length of the tube), 9 per cent (size of the hole), and 2 per cent (level of water), of the pupils. Here it is interesting to note that the third variable is more open

to observation than the second one. Lastly, pupils experience difficulty in verbalizing their methods of attack despite the fact that they are aware of the solution of the problem to a great extent. This difficulty, how ever, disappears when the problem is found fully mastered. It is only in Grade X that a few of the pupils are in a position to verbalize their methods of attack. Here also, the role of the problem selected is critical

16. The adolescent pupils ask all sorts of questions, some of them are quite simple and others are not even questions at all. Some examples of the latter are :

(i) Man rides on the cycle (It is a statement of observation and not a question at all).

(ii) The cycles and cows are of many colours (Statement).

(iii) Is cow a ball of fire ? (A carry-over of the question used as illustration : Is sun a ball of fire ?).

It is anybody's guess why these questions should agitate their minds. Secondly, it is interesting to note that the accepted questions ran into seventeen distinct categories. Thirdly, fluency and flexibility as defined in this study were strongly correlated ($r = .6023$, significant at 1 per cent level).

17. The complex problem-solving processes arise from simple thinking processes. It is precisely for this reason that items relating to the following schemes of thought come out late in development : generalization to algebraic symbols, testing hypotheses, using insight, and failure to grasp the essence of the problem Further, it needs well developed schemes of thought of Using constant difference, Using

summation and Using proportion before the relationship : Extension is proportional to the stretching force emerges or is discovered, a process which appears mastered, largely speaking, in Grade X,

18 Except occasional fluctations, the grade means on the various schemes of thought show an increasing trend with age. Close analysis of the various means indicates that all the schemes of thought do not develop equally across the grades. For example, generalization to algebraic symbols (summation) and testing hypotheses evolve marginally in pupils of Grade VI through X.

19. Using Principal Component Analysis on the combined matrices containing 45 variables and the varimax rotated factor structures with a view to obtain the hypothesized factors and interpret them psychologically, the following multiple factors appeared : (i) Schematic learning general, (ii) Adjustment, (iii) Problem orientation, (iv) Sensing problems, (v) Symbolization, (vi) Testing hypotheses, (vii) Using constant difference, aed (viii) Aspect character (single).

20. Problem-solving, largely speaking, favours boys rather than girls. Right throughout the grades, both try hard to equalize their performance. Considering the pooled sample sex-wise (N = 100 boys and girls each) and the conventional levels of significance, it was found that significant differences between the two were found on four problems as well as seven schemes of thought out of 17 problems and 17 schemes of thought. Considering the conventional levels of significance, the top group differed significantly from the bottom group in home adjustment, health adjustment, emotional adjustment, social adjustment school adjustment

and understanding of the problem and all the seventeen schemes of thought. Lastly, the teacher evidence when collected informally showed that most of the unsuccessful problem-solvers are highly distractable, show poor concentration and are little interested in school work which was, however, not the case in the case of successful problem-solvers.

Educational Implications

Several educational implications emerge from this study. First, immediate test reactions to the problems on presentation are highly individual reactions which definitely set a tone for solving a given problem So the very choice of problem is very critical in the development of thinking. Secondly, it is very necessary to use those problems which have clear-cut solutions. The workable proposition appears to be that of analysing known problems in such a way as to develop research skills. Thirdly, this study has shown that the use of pin-pointed questions helps students in thinking specifically. Fourthly, certain schemes of thought like scheme of proportion, generalization to algebraic symbols and testing of hypotheses come out late in development. This finding highlights the problem of providing psychological support at the critical points to the various school subjects. Fifthly, a given problem or a process in the thought structure of a problem is passed or failed over a wide IQ range not only within the individual grades but also across the grades as well. This shows that vast individual differences in problem solving exist. Lastly, as expected, adolescent pupils commit a large number of errors while engaged in problem-solving. Pupils need training in asking searching questions.

Study No. 2

A Factorial Study of Adolescent Thought Using Piaget Type Tasks

Focus

The scientific investigation of thinking processes is gaining importance because the development of a highly logical mind is a sine qua non of the modern scientific world and thus the most important goal of instruction also. Jean Piaget has contributed a lot regarding the modes of development of human thinking. He has concentrated mainly on the qualitative changes that take place in thinking processes from time to time with the advancement of age and lead to the mental growth of an individual. Brainerd (1978) has summarised the Piagetain view point as, "It does not see process of growth merely as a matter of continuous and quantitative improvements in the thought processes that remain qualitatively constant throughout the life span of an individual, rather it considers the qualitative changes in the underlying processes of thinking themselves as a fundamental fact of mental growth". Piaget has grouped these qualitative changes in thinking into four global stages of development, i. e , sensori-motor stage (birth to 2 years), pre-operational stage (2 to 7 years), concrete-operational stage (7 to 11 years), and formal-operal stage (11 to 15 years). Later on, he hypothesised the existence of formal-operational stage upto 20 years of age as well as diversification of aptitudes during this period.

Another important feature of Piaget's theory is that it has always stressed on study of the structure of human thinking than its function and content alone.

The present study was undertaken with a view to investigate the structure of thinking at formal-operational stage-the most important period from the point of view of instruction. Since there is a sufficient research evidence that in majority of the cases, adolescents at the age level (11 to 15 years) do not attain the level of formal thought in the true Piagetian sense, the term adolescent thought has been used to describe the thinking of the adolescent at this age which shows a form of grouping of concrete-operational and formal-operational thought. The effort has been made in this study to analyse the adolescent thought mathematically, using factor analytical technique, to identify its underlying structure, and to explore the extent of the relation ship, of the development of adolescent thought with age, sex, intelligence, academic achievement, reasoning ability, space relations, adjustment and fourteen dimensions of personality.

Hypotheses

In the light of the related research studies reviewed, the following hypotheses were proposed to be tested through this study :

1. The performance on Piaget Type Tasks increases with age during the formal-operational period.
2. Boys and girls perform equally well on Piaget Type Tasks.
3. The measures of intelligence, both verbal and non-verbal, correlate significantly with the measures of the dimensions of adolescent thought.

4. There exists a significant relationship between the measures of academic achivement and the variables of the dimensions of adolescent thought.

5. The measures of reasoning ability and space relations yield a significant correlation with the various measures of adolescent thougt.

6. The measures of adjustment is significantly related to the performance on Piaget Type Tasks.

7. The measures of personality exhibit significant relationship with the measures of the dimensions of adolescent thought.

8. The performances on Piaget Type Tasks forms an interrelated measure of the adolescent thought and exhibits a unifactor structure.

9. The measures of intelligence, academic achievement, reasoning ability, space relations, adjustment and other personality traits cluster in specific constellations with the measures of the dimensions of adolescent thought explaining there by the common factor variance.

Sample

A sample of 986 students (505 boys and 481 girls) was drawn randomly among the students of twelve high schools of rural areas in Punjab taking almost equal number of boys and girls from the age groups of 11^+, 12^+, 13^+, 14^+, and 15^+ and studying in grades VI, VII, VIII, IX and X respectively.

Tools of Research

The data were collected using the following tools :

1. Test of Piaget Type Tasks (author).

2. Culture Fair Intelligence Test-Scale 2 (Cattell & Cattell)
3. General Mental Ability Test (Jalota).
4. Reasoning Ability Test (Dubey).
5. Space Relations (DAT) (Bennett, et al).
6. Adjustment Inventory (Asthana).
7. High School Personality Questionnaire (Cattell & Beloff)
8. Academic Achievement in Five School Subjects (from School Records).

Statistical Treatment of Data

To identify the factorial structure of adolescent tdought, data on the 34 measures were put into 34 × 34 correlation matrix and subjected to factor analysis by Principal Axes Method with Varimax Rotation. The computations were carried out through "REYAD-1022 Computer" at Computronics India, New Delhi, using PA-1 factor analysis programme from the Statistical Package for the Social Sciences (SPSS) by Nie, et all (1970). The relationship beween the measures of adolescent thought and the other independent variables were worked out by computing product-moment coefficients of correlation. One-way analysis of variance technique was used to determine the age and sex differences regarding the performance on Piaget Type Tasks.

Conclusions

1. The performance of adolescents on Piaget Type Tasks increases with age during the formal-operational period.
2. The performance of boys on some of the Piaget Type Tasks at certain age levels is superior to that of girls while there is no significant difference in the remaining cases.

3. The measures of intelligence, both verbal and nonverbal correlate significantly with the measures of adolescent thought in the positive direction.

4. The academic achievement is having a significant positive relationship with the measures of adolescent thought.

5. The measures or reasoning ability and space relations prove to be some of the determinants of the development of adolescent thought.

6. The development of adolescent thought leads to the better adjustment of the individuals or vice-versa.

7. Personality traits like outgoing-tendencies, abstract thinking, emotional stability, phlegmatism, obedience, conscientiousness, adventurousness, feeling of security, self-discipline and relaxedness go with the development of adolescent thought where as reservedness, concrete thinking, emotional instability, excitability, assertiveness, expedience, shyness, feeling of insecurity, uncontrolability and tenseness go with the non-development of adolescent thought.

8. The performance on Piaget Type Tasks forms an interrelated measure of adolescent thought which exhibits an unifactor structure.

9. Eight significant factors, extracted through factor analysis, account for 49% of total variance, and are named as : General Intellectual Factor of Adolescent Thought, Academic Achievement Factor, Adjustment Factor, Behavioural Factor, Emotional Factor, Temperamental Factor, Group Factor of Adolescent Thought and Social Factor

Study No. 3

A Study of Problem Solving Behaviour In Physics Among Certain Groups of Adolescent Pupils

Introduction :

Educators rarely agree as to which content and forms of instruction are the best, but there is one aspect of science teaching where there is a remarkable degree of agreement in the belief of present-day science educator. It is the belief that, "problem solving" has an important place in the learning of science in schools. Problem solving is the framwork or the pattern within which creative thinking and reasoning take place. It is the ability to think and reason at given levels of complexity. It has been observed that some pupils, having a particular intellectual ability, can solve a given problem, where as, others can not. The study of the problem solving behaviour of the pupils having different intellectual abilities in relation to the problems of different complexitis in each discipline is an exciting challenge for psychologists and the science educators. Physics is considered to be at the apex of all the sciences. It deals with the proper use of logic and the scientific method. Therefore, the area of study was restricted to the discipline of Physics only. Further, it has been observed that many a times, the students wrongly answer or are even unable to attack on a given problem because of the fact that they are not conscious about its multiple interesting parameters. For making the students conscious of the problem, they may be asked to answer a set of questions which may not provide any direct clue for the correct answer but may simply act as a 'hint' and lead them to thinking in the appropriate direction for arriving at a correct solution.

Objectives of the Study

The study aims at investigating the following objectives :

1. To identify the basic problems in Physics having direct bearing on the various reasoning patterns.
2. To study the problem solving ability of adolescent pupils, boys and girls at high, average and low IQ levels, high, average and low creativity levels and formal, post-concrete and concrete levels of students.
3. To study the relationships between the scores of different problems obtained before providing hints and after providing hints.
4. To study the attainment in intelligence, creativity and the level of intellectual development scores of the successful, partially successful and unsuccessful problem solvers.
5. To study the difference between the scores before and after providing hints concerning each problem.
6. To determine the mathematical structures of the problems and other variables included in the study.
7. To point out the main educational implications for problem solving based upon this study.

Hypotheses to be Tested

It is proposed to test the following hypotheses :

1. There are significant differences among the students with regard to the following variables : (i) Total scores of all

the problems before holding interview (or before providing hints) for boys and girls (PSAT); (ii) Total scores of all the problems after the interview (or after providing hints) for boys and girls; (iii) 'Before' and 'after' hint scores of each problem; (iv) Successful, partially successful and unsuccessful problem solvers; in the groups of the three levels of intelligence (high, average and low IQ), in the groups of the three levels of creativity (high, average and low creativity) and also in the groups of the three levels of intellectual development (formal, post-concrete and concrete).

2 There is a significant relationship between the following variables : (i) Scores of each problem before hints; (ii) Scores of each problem after hints; (iii) Scores of problem solving ability test (before providing hints) in relation to IQ, creativity and level of intellectual development; (iv) Scores of Problem solving ability test (after providing hints), in relation to IQ, creativity and level of intellectual development.

3. There are significant differences in the scores of I. Q. creativity, level of intellectual development of the successful, partially successful and unsuccessful problem solvers.

4. There are strong unitary factorial structures underlying the measures of I.Q., creativity, level of intellectual development, academic achievement and the reasoning patterns of the problems in Physics.

Method of Study

I. Sample

The sample of the study was delimited in terms of the geographical location and academic level of students. The study was confined to the higher-secondary schools of Ajmer city only for reasons of facility and convenience. The study was conducted on 180 pupils: 90 boys and 90 girls of class XI (science). The pupils were selected randomly and were of average socio-economic status and in the age group of 14^+ to 16^- years.

II. Research Design

This is an Ex-post facto research study under the descriptive method of research. Further, the randomized-blocks design and within subjects design was used in the present study. Here the subjects were grouped into such blocks that the subjects within each block were relatively homogenous with respect to some other blocks for the same variable. The subjects were divided in the three blocks according to the I.Q. level : high I.Q., average I.Q., and low I.Q. Similarly the subjects were also grouped in three blocks according to their scores in creativity and Piagetian tasks. The scores for each problem in these groups before interview and after interview (before providing hints and after providing hints) were compared. Further, the differential, correlational and factor analysis techniques were used to carry out the present study.

III. Variables in the Study

To measure the different intellectual abilities of each pupil, the following thirty four variables were investigated in the present study :

1. Intelligence.

2-6 Levels of intellectual development.

7-25 Reasoning patterns.

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26-27 Problem solving ability.

28-31 Creativity.

32-34 Academic achievements.

IV. Tests Used

The following standard tests were used to measure the IQ, creativity level of intellectual development, reasoning patterns and the problem solving ability etc.

1. Raven's Standard Progressive Matrices, Sets A, B, C, D, and E to measure IQ.
2. Verbal test of creativity by Baquer Mehdi to measure Fluency, Frequency, Originality and Creativity.
3. Four Piagetian tasks to measure the level of intellectual development.
   - (i) 'Conservation of Volume' using metal cylinder task.
   - (ii) 'Exclusion of irrelevant variables', using Pendulum-task.
   - (iii) 'Proportional reasoning' using the Equilibrium in the balance task.
   - (iv) 'Separation and control of variables,' using the bending of rods task.
4. The Academic Achievement in Physics, Chemistry, Mathematics. Biology and Science is the percentage of the scholastic achievement scores obtained in respective subjects at the high school examination conducted by the Board of Secondary Education, Rajasthan, Ajmer.
5. Ten problems in Physics based on different reasoning patterns to measure the problem solving ability (PSAt) were framed and standardized by the researcher.

The reasoning patterns and the abbreviations used for the problems are mentioned in the following table :

Problems Having Following Reasoning Patterns Were Selected for the Study

Serial No. of the Problem	Reasoning-Patterns	Abbreviation
1.	Proportional Reasoning	Pr
2.	Additive Reasoning and Proportional Reasoning	Ad pr
3.	Creative thinking and Proportional Reasoning	Cr Pr
4.	Propositional reasoning	Ps
5.	Experimental Reasoning (Formulation and Testing of hypothesis)	E
6.	Hypothesico-Deductive Reasoning	Hd
7.	Interactional Reasoning	I
8.	Creative thinking and Probabilistic reasoning	Cr Pb
9.	Conservation reasoning and Functional reasoning	COE
10.	Separation and Control of variable reasoning	SCv
	Problem solving ability or Total Scores on all the problems	PSAt

V. Administration of the Tests

The Raven's progressive matrices test, creativity test and problem solving ability in Physics test were administered in a group of 15 to 20 students at a time. The Piagetian tasks were administered individually to each student.

The solutions of the problems were evaluated carefully and the problems which were not answered or wrongly answered were noted down on the answer sheets of each student. Each student was asked a set of questions on each such problem. Care was taken so that the questions may not provide any direct clue for the correct answer but may simply act as 'hints' and lead the students to thinking in the appropriate direction for arriving at correct solutions of the problems.

VI. Major Findings

The subsidiary findings, being numerous, are not mentioned here. The major findings of the present study are as follows :

1. Problem solving ability scores differ significantly at 1% level of significance among the three groups of IQ and also among the three groups of the levels of intellectual development. The same result was obtained when the problem solving ability scores after providing hints were considered. No sex differences were noticed in the above mentioned groups.

2. The 'before' and 'after providing hint scores' for each problem showed highly significant difference at 5% and 1% levels of significance in the each group selected separately of the three levels of IQ, the three levels of creativity and the three levels of intellectual development.

3. Out of the 45 correlations among the problems, most of the correlations were found significant. Similar picture was retained when the correlations among the problems after providing hints were considered.

4. When the scores were classified under successful problem solvers, partially successful problem solvers, unsuccessful problem solvers for each of the problem, no uniform pattern was observed with regard to the classification

of the pupils at the three levels of IQ, creativity and the levels of intellectual development. It is, however, seen that in most of the problems, higher level of intellectual development, as measured by the Piagetian tasks, favours problem solving. After providing hints, most of the unsuccessful students in each group were able to solve the problems but no uniform pattern was observed with regard to the classification of the pupils.

5. The scores of the levels of intellectual development differ significantly at 1% and 5% levels of significance among the groups of successful, partially successful and unsuccessful problem solvers for most of the problems. On the scores of IQ also these groups differ significantly from each other for most of the problems. However on the scores of creativity these groups differ significantly only in the two problems (Cr Pr and Cr Pb).

6. The mathematical structure of the variables selected for the present study using Hotelling method indicated the existence of the three factors, which were interpreted psychologically. The three factors are :

   (i) General Schematic learning

   (ii) Creativity

   (iii) Academic achievement in Science.

Study No. 4

The Growth of Exclusion of Variables During Adolescence - A Study

Introduction

It is a strange paradox that 'explosion of knowledge' of today has given man unlimited power on one hand and on the other, has opened out a possibility of it being used for his total annihilation. This is an age of 'Space travel' as well as of 'Atomic energy'. Life is no more simple as it was, it has become challenging and complex. Over the centuries, philosophers and, later, the psychologists tried to study and explain human behaviour and the human mind. They succeeded only partially and failed to give a total picture of the working of the human mind. Educationists and psychologists, today have taken a keen interest in studying and understanding the various thinking processes underlying the working of the mind. The 20th century psychology believes that "....the life of the mind is a dynamic reality, intelligence a real and constructive activity" (Modgil, 1974). The late Prof. Jean Piaget (1896-1980) who, by his intensive research over the years right until death, wrote a large number of articles, papers, monographs and books and gave the world the famous 'Piagetian theory' of cognitive development called the 'Geneva School' which explains the development of cognition qualitatively from birth until the first 20 years of life. According to Piaget, intelligence develops in four stages. These are : Sensory Motor (0-2 years), Pre-logical (2-7 years), concrete (7-11 years) and Formal (11-15 years). Recently, he had hinted at the possibility of a fifth stage which covers the period from 15 to 20 years after taking into account factors like aptitude variations and commitment to individual careers against the back drop of now less prominent general intellectual development. The first stage is of little educational significance. In the second stage, the thinking or reasoning is transductive and intuitive. In the third one, reality dominates thinking which is reversed in the fourth where possibilities are proposed and examined. The ultimate equilibrium of intelligence (even abstract thinking) is found in this stage. The development of abstract reasoning among adolescents is more urgent today than ever before to help them tackle the complex situations man is confronted with at present. Abstract thinking is essential for learning science as one is required to manipulate ideas and possibilities in the mind. The present study was undertaken with a view to investigate the thinking processes the adolescents adopt for solving problems, in particular, the stating the testing of hypotheses ability which is a basic character of the formal operational stage.

Aims and Objective

The study aims at investigating the following :

1. To investigate adolescent thought through a short, reliable and valid test instrument; incorporating Piaget type tasks.
2. To determine the relationships between the scores on certain aspects of exclusion of variables and some out

side variables, Age, Sex: Intelligence, Personality Characteristics and Aptitude.

3. To analyse the structure of exclusion of variables along with three other schemes of thought (Permutations and combinations, Problem sensitivity and Grasping the essence of the problem).

4. To determine the Characteristics of successful and unsuccessful problem solvers on Piaget type tasks.

5. To point out the main educational implications based upon the findings of the study.

Hypotheses Proposed to be Tested

It is proposed to test the following hypotheses :

1. Adolescent pupils consider and exhaust all possible hypotheses before they begin to test them.

2. The hypotheses are stated and tested successfully in all the age groups.

3. Adolescent pupil is attracted more by the content than the form of the problem.

4. There are no significant differences in performance of successful and unsuccessful problem solvers on the following variables :
    - (i) Stating of hypotheses.,
    - (ii) Testing of hypotheses.

5. There are no significant sex differences on the following variables :
    - (i) Five schemes of thought.,
    - (ii) Selected personality variables.,
    - (iii) Selected measures of aptitude tests.

Method of Procedure

Sample

The sample consisted of 200 students (100 boys and 100 girls) drawn randomly from Middle and High Schools of Urban area (Mysore), belonging to 10+, 11+, 12+, 13+ and 14+ years age levels studying in grades VI, VII, VIII, IX and X respectively. Each grade represented equal number of boys and girls All the schools were private institutions following the syllabus prescribed by the Karnataka Secondary Board of Education and the medium of instruction of the sample was English.

Tests Developed

Twelve Piaget type tasks were finally chosen by the investigator. They were written in the questionnaire form. The tasks were not administered enmasse but they were presented in three separate questionnaires of four, three and five tasks each as follows. The reliability and validity of the tasks as found are given along with.

S. No.	Questionnaire	Piaget Type Tasks	Reliability	Validity (Abstract Reasoning (DAT)
	I Stating of Hypotheses			
1.		The flow of liquid through a tube problem Q_1 P_1 (SOH)	.77	.272
2.		The simple pendulum problem Q_1 P_2 (SOH)	.41	.205
3.		The remp problem Q_1 P_3 (SOH)	.72	.357
4.		The seed problem Q_1 P_4 (SOH)	.43	.454

	II Testing of Hypotheses			
1.		The flow of liquid through a tube problem Q_3 P_1 (TOH)	.85	.067
2.		The simple pendulum problem Q_3 P_2 (TOH)	.71	.196
3.		The ramp problem Q_3 P_3 (TOH)	.76	.266
	III Some Interesting and Funny Questions			
1.		Digital problem DP (PAC)	.78	.276
2.		Formulating questions problem (FQP)	.77	220
3.		Questions inviting wrong answers problem GEP	.49	.353
4.		Magic seeds problem MSP (PAC)	.58	.411
5.		The Worms problem Q_3 P_5 (TOH)	.79	.192

Other Standardized Tests Used

1. Culture Fair (Free) Intelligence Test (Scale II-Form A) Cattell and Cattell.
2. High School Personality Questionnaire (HSPQ)—Cattell and Cattell.
3. Aptitude Tests (DAT)
   - (i) Abstract Reasoning.,
   - (ii) Verbal Reasoning.,
   - (iii) Numerical Ability.,
   - (iv) Mechanical Reasoning.,
   - (v) Space Reations and
   - (vi) Language Usage.

Statistical Treatment of Data

The growth of 'Exclusion of variables during adolescence', that is, the 'Stating and Testing of hypotheses' ability of adolescent boys and girls (N = 200) was studied in relation to other factors like Intelligence (Non verbal), Personality (HSPQ), Aptitude (DAT), Permutations and Combinations, Problem Sensitivity and Grasping the Essence of the problem (Schemes of adolescent thought). In all, there were thirty nine variables whose data were computed, Using the programme MARGINALS with ALL STATISTICS from Statistical Package for the Social Sciences (Nie et al., 1970) through 'REYAD-1022 Computer' at Computronics India, New Delhi.

The statistics computed were mean, standard deviation and t value sex-wise for all the variables for the whole sample as well as for sub samples to test the various hypotheses stated earlier. The mathematical structures of the various tasks and tests were also determined.

Main Findings

The main findings of the study indicated.

(i) Adolescent pupils are in a position to state and test hypotheses in all grades. However, the mean performance increases with grade with occasional fluctuations.

(ii) The majority of the successful (top group) problem solvers are the fourteen year olds and the majority of the unsucccessful (bottom group) problem solvers are the ten year olds for both stating and testing of hypotheses.

(iii) Adolescent pupils of this sample too, as in the case of earlier researches do not attain the formal operational level of thinking. Most of them are still found to operate at the concrete level.

(iv) Out of the thirty eight variables of IQ, DAT, HSPQ and Piaget type tasks (excluding age–which was controlled) twenty two variables did not show any sex difference. Of the sixteen with significant sex difference, nine favoured boys and seven girls.

(v) Age was found to be significantly correlated with all the measures of exclusion of variables. Certain traits of personality correlated with specific measures of exclusion of variables and except a few, most of the Aptitude tests were found be significantly correlated with all the measures of exclusion of variables. Where as formulating questions problem was correlated significantly with certain measures of exclusion of variables, Permutations and Combinations and Grasping the essence of the problem were found to be significantly correlated with all the measures of exclusion of variables.

(vi) Considering the entire sample (N = 200) and the entire tasks and tests (N = 39) using the Hotelling Method (Varimax rotation) as well as the Scree test as propounded by Prof. Cattell, the following eight factors appeared :

S. No.	Order of factors	Its Psychological Nomenclature
1.	First factor	Language Factor
2.	Second factor	Exclusion of Variables (Testing Hypotheses)

3.	Third factor	Exclusion of Variables (Stating Hypotheses)
4.	Fourth Factor	Super Ego Strength
5.	Fifth factor	Group Factor of Personality (Dominance, Guilt Proneness, Ego Strength)
6.	Sixth factor	Permutations and Combinations
7.	Seventh factor	Mechanical Reasoning
8.	Eighth factor	Self Sufficiency

Study No. 5

The Role of Hypotheses in Solving Problems of Science

Introduction

Why THIS STUDY ? It is a very good opening question which needs to be answered first. There is a wide spread impression accepted uncritically that there is something fundamentally wrong with our present day teaching and learning of science. It is being said day in and day out that science teaching in our country suffers from several defects. First, it is too bookish in character. Secondly. it ignores the real natu: and spirit of science. Thirdly, it is approached wrongly because the teacher is always in a hurry to cover rather than to uncover the course. Fourthly, it ignores the development of functional knowledge, acquisition of skills, attitudes, and appreciations. Fifthly, it is little related to the environment in which children live. Lastly, science students hardly make use of their 'talents and tools' in their day to day learning of science.

It is not, however, inappropriate to point out at this stage that the criticism of this sort is based on untested evidence. It will be of interest to refer in this connection to the Geneva School. Its leading advocate, Jean Piaget, using highly imaginative and thought provoking experiments, has demonstrated that formation of hypotheses, regardless of the influence of school instruction on intellectual development comes naturally to adolescent pupils beyond the age of eleven, the incidence of this age being different in different cultures. But at the same time, the sequence of development in each individual remains more or less the same (the concept of epistemic subject). Using clinical method and covering a wide age range (36 hours to over 16 years). Piaget and his collaborators appear to say some what as follows.

Intelligence develops in stages. During the first stage (prelogical), the child's thinking is governed by the perceptual considerations of the situation. He makes judgement the way he sees the situation. His reasoning is transductive, that is, he reasons from particular to particular with complete unconcern for finding. At the concrete stage, reality dominates his thinking and possibility is subordinated to it. He even refuses to accept the data with which he does not agree. He can, however, return to the starting point of his thinking which was not the case at the preceeding stage. At the formal stage, he can set up all sorts of hypotheses, test them against the given data, set up control experiments with a view to distinguishing between relevant and irrelevant hypotheses, developing and applying mathematical thinking in varied contexts, and gaining insight into the nature of proof. He begins to see clearly well the consequences of his thoughts and actions To stress, it is during this stage only that he is capable of picking up the various elements of scientific methods, and other concept requiring clarification when seen from the angle of the history of science. Piaget then links these stages with symbolic logic—a branch of mathematics. It is by the establishment of this logical link in the study of intellectual operations that gives his entire work a highly distinctive character. (2) Using Piaget type task, the present study was undertaken to investigate the role of hypotheses in solving a few problems of science requiring no specialized knowledge and information on the part of adolescent pupils.

Past Work

It is not difficult to see the present problem either from the angle of the conventional learning theories or the growth of logical thinking as propounded by Jean Piaget. Consolidated information on this is available elsewhere. Here let us only refer to a few significant studies having some bearing on this problem. Buswell investigated the thought processes of a group of subjects (school children and college students) and attempted to describe individual patterns of thinking objectively if these at all exist: His results indicated that subjects experienced difficulty in expressing concepts verbally which they had in fact acquired, they do not estimate the answers before they start solving problems, and lastly, variety rather than similarity in the sequence of thinking was the most striking and outstanding characteristic even when common and uniform patterns of thinking were seen to emerge on total analysis of their responses. Benjamin and Burrack, while studying reasoning of 25 psychology undergraduates, found it very difficult to distinguish among different methods of attack. Using puzzles, Heidbreader and Mumford investigated thinking and noted gradual growth in problem solving behaviour. The latter emphasized that thinking be regarded as a mental skill based upon innate capacity. Durkin tried hard to distinguish among three different types of solutions, namely trial and error, sudden organisation and gradual analysis, and further showed that observation, recall, seeing relations, attention to the goal manipulation and inference were the processes present in all the three forms of thinking. Bloom and Broader, while working on successful and unsuccessful problem solvers, showed that successful problem solvers did not only manifest restricted thought but also made a greater use of their fund of knowledge. Wheeler investigated the development of reasoning among children and showed, contrary to Jean Piaget, that children possess logical reasoning at much earlier age than hitherto considered.

Several workers like G. Stanley Hall, Deutsche, Oakes, Navarra and Charren George have investigated thinking with special reference to science. It is impossible to compare their findings because their aims and objectives, sample subjects and tests, manner of analysing data have been quite varied in character. Vaidya also carried out a study on problem solving in science among certain groups of adolescent pupils (15+). The results of this study indicated that, contrary to Piaget's view, the adolescent pupil also criticize data. Secondly, there is a general tendency among adolescent pupils to set up hypotheses which they test against the given data. A poor problem solver appear to stick to one idea at a time stubbornly and, later on, ceases to think of alternative ideas. While examining continuities and discontinuities in thinking of adolescent pupils evoked by Piaget type tasks, Vijaya Luxmi and K. R. Sayal found that thinking processes, when appropriately grouped, within restricted age range, constitute a Guttman scale. In sum, it can be safely concluded that several studies, general and specific, are urgently needed to investigate thinking with a view to develop a fruitful model of thinking, which may throw light on learning, problem solving, intelligence and even creativity.

Aims and Objectives

The present study aims at investigating the following :

(i) To study the role of hypotheses formation in solving problems involving a continuous chain of reasoning;

(ii) To analyse the same in terms of basic processes needed to solve all problems regardless of their type;

(iii) To study the problem solving process in relation to intelligence, adjustment and immediate reactions to the problems on presentation;

(iv) To find out the characteristic of successful and unsuccessful problem solvers;

(v) To analyse the structure of the problem mathematically through factor analysis and interpret them psychologically, and lastly;

(vi) To point out the educational implications of the study.

Method and Procedure

It comprised the following steps :

(a) Sample and subjects : Fifty students of class X of the St. Paul Higher Secondary School, Ajmer constituted the sample. The following constraints were imposed on the sample. Firstly, only pupils of the age of 15 + were included. Secondly, those who had failed even once at school were excluded from the study. Thirdly, all pupils belonged to more or less the same socio-economic status. Fourthly, all the pupils belonged to the urban area.

Their intelligence and adjustment were measured by Jalota's Group Test of General Mental Ability (1960) and M. S. L. Saxena's Adjustment Inventory. The latter provided scores on the following five measures of adjustment : home, health, social, emotional and school.

(b) Problems used : Several problems were considered. The basic objective was to seek those problems, which evoke diverse problem solving behaviour; and which could be seen through the medium of hypotheses as proposed by the adolescent pupils. Finally the following five problems were selected for investigating the thought processes.

(1) Combinatorial Grouping Problem: You are given four numbers: 6,7,8 and 9. Form as many digits as possible from these numbers.

(2) Framing Questions: Make as many questions as you can, whose answers you do not know, on (i) cow, (ii) water, and (iii) cycle.

(3) Three Rods Problem: Identifying the materials of rods by proposing tests. Once, you were given three small rods just similar in all respects, say, in length and appearance etc., by your science teacher. These rods were made of iron, wood and sugar. How will you distinguish which rod is made of which material ? Perform all experiments or propose tests by which these rods can be distinguished. Remember that you are to propose as many tests as you can.

(4) Beaker Problem. There is some liquid in a beaker. A hollow tube is fitted near the bottom of the beaker as an outlet. There is another empty beaker kept below the filled one. On what factors does the filling in of the empty beaker depend ? It you need stop-watch, it is supposed to be given If you need anything more, that is also supposed to be given.

(5) Simple Pendulum Problem: A simple pendulum is swinging. On what factors will the time period of the simple pendulum depend ? Propose control experiments to isolate the irrelevant variables.

(c) Manner of Presentation: The above mentioned problems were presented as follows :

First a special letter was drafted for acquainting the students with the aims of the study. Other clarifications when sought, were orally given. Secondly, the problems were presented in two sessions in a group situation and completed in four periods, each of 40 minutes duration. Extra time was given to those who demanded. Thirdly, every pupil was asked to give his personal pre-test reactions on three of the problems by answering a series of six different questions. These questions were :

(i) Have you done a problem of this type before ? Yes or No.

(ii) Did you find this problem difficult ? Yes, little, No.

(iii) Do you understand this problem ? Yes, little, No.

(iv) Did you solve this problem ? Yes, little, No.

(v) Do you find any difficult word in the problem ? Yes or No.

(vi) Did this problem interest you ? Yes, little, No.

(d) Manner of Scoring: Being a qualitative study, the scoring employed was simple, that is, one mark each for every acceptable response there being no upper score for any-one of the problems used. After administration of the problems, the scoring key was developed. The maximum scores for the various problems mentioned in order above were found to be 62, 36, 8 and 10 respectively. Immediate reactions to the problems on presentation were rated on a two to three point scale on three rods problem, beaker problem and simple pendulum problem only.

Main Findings :

The main finds of this study indicated :

1. Reactions to the Problems :

It was hypothesized that pupils first make up their minds before they begin to solve problems. Six questions were asked to know their snap judgement on the problems which were evaluated on two or three point scale. A summated score for every individual on all problems was thus obtained. When correlation between summated scores on immediate reactions and the various problem solving processes were computed, it was found that confidence shown in the problem was significantly correlated with setting up of control experiments, and proposing tests at 1 p.c. level (r = .367 and .434); and with formulating hypotheses at 5 p. c. level (r = .327). Difficulty of the problem was correlated with using two digits and proposing tests at 5 p. c. level (r = −0.302 and −0.307). Understanding of the problem and interest in the problem were found to be significantly correlated with using two digits and formulating hypotheses at 5 p. c. level (r = .280 and .297). All the other correlations were found to be insignificant at 5 p.c. level.

2. Combinatorial Grouping Problem

Generally speaking, the adolescent pupils show the Combinatorial Grouping behaviour to a varying degree. Maximum score being 62, the scores on two digits, three digits and four digits have ranged from 2 to 12 (out of twelve; and 0 to 24 (out of 24) for the remaining two combinations. It is only about 8 p. c. of the pupils who appear to have tackled the problem systematically as well as exhaustively, that is, exhausting all the possible combinations. It is a telling comment on education that six pupils whose raw scores on intelligence test ranged from 63 to 80 (mean = 65 and S. D. = 10.65) could not at all suggest even a single three digit combination. Two could not suggest even a single four digit, combination. On the whole, it appears, that students did see the problem as a whole and then tackled it in their own characteristic way. Two digit combinations were given first which were followed by three digit and four digit combinations. With the gradual growth of the solution, they did try to write down those combinations which they had missed earlier but, on second reflection, very few of them appear to have exhausted all the available combinations.

Two digit combinations have been given by most of the pupils. Seventy eight per cent of the pupils could visualize the following three digit combination 678. But this percentage fell down to fifty six percent in case of the 789 combination. It is strange to point out that more than two thirds of the pupils could not visualize the following three digit combinations : 869, 769, 796 and 897.

The following four digit combinations were found to be very easy to visualize : 6789 (82 p. c.) 9876 (68 p. c.), 7689 and 8679 (66 p. c each). On the other hand, the following four digit combinations were found to be very difficult to 6798 (32 p. c.) 7698 (30 p. c.) and 9786 (10 p. c.) & 9786 (6 p. c.).

Taking two extreme groups, that is, top 10 p. c. and bottom 10 p. c. on the over all basis of performance on five problems, it was found out that these two groups differed from each other both at 5 p. c. and 1 p. c. levels on three digit as well as four digit combinations.

3. Framing Questions Problem : (Whose answers students do not know).

Combining the number of questions on three items, namely, cow, water and cycle, it was found that the maximum and the minimum number of questions were 36 and 8, mean and standard deviation being 18.76 and 7.03. As usual, the two extreme groups differed from each other both at 5 p. c. and 1 p. c. level in their ability to frame the above mentioned types of questions. This is not an unexpected finding. Below is presented a list of 5 accepted and rejected questions.

Accepted Questions :

(i) Is the heart of cow the same as that of man or child ?

(ii) How many nutritional elements are found in milk of cow ?

(iii) Why do not Hindus eat cow's meat ?

(iv) Why is the density of water fairly constant at 4°c ?

(v) Who was the inventor of cycle ?

Rejected Questions

(i) Why cows do not write ?

(ii) The cows have four legs ?

(iii) Why is it essential to have a cycle ?

(iv) Can cycle fly in the air ?

(v) Is water costly ?

It was found that students ask all sorts of questions from the significant areas of human living. The starting words of these questions were : WHY, HOW, WHERE, WHO, WHEN, WHAT and so on.

4. Three Rods Problem

The pupils proposed eight different tests for identifying the materials of the three rods : immersion in water; use of magnet; using electricity; burning; hammering; tasting; Ingenhouze experiment; and by throwing them on the earth. The average mean and standard deviation of the number of tests proposed are 2.78 and 1.38. For a select science group like the one under study, the average number of tests proposed is quite low. It is, therefore, safe to conclude that on this problem, pupils have not made use of their scientific knowledge because the most popular two to three tests proposed were : immersing them in water and tasting. They did not at all refer to other valid tests : Use of acids, computing density, chemical analysis of iron, rusting, suspending weights, etc. It is, therefore, least surprising that the two extreme groups did not differ from each other on the number of proposing tests on common materials like wood, sugar and iron.

5. Beaker and Simple Pendulum Problem

On these two problems, the pupils identified the following variables : length of tube, pressure of water, height of the beaker, viscosity of the liquid area of cross section of the tube; and weight of the bob, volume of the bob, length of the pendulum, value of 'g' and length of the swing sideways. The means and S. Ds. on these variables are 6.44 and 1.98. The maximum and minimum number of hypotheses on both the problems (only two pupils could not hypothesize at all) proposed are 10 and 0. The top group and the bottom group did not differ significantly in their ability to hypothesize at 5 p. c. and 1 p c. levels. On the whole, the group appears to be fairly homogeneous in proposing hypotheses. This finding supports Piaget, for according to him, the adolescents are quite capable of setting up varied hypotheses where reality is subordinated to possibilities. It is interesting to point out that there is no significant correlation between setting up hypotheses and proposing tests on objects of daily use.

Regarding setting up control experiments, the mean and standard deviations are 2 and 1.78, range being 0 to 6. There is no significant difference between the top group and the bottom group on the ability to set up control experiments for the very reason that this ability does not appear to have developed among X grade students. It is interesting to point out that the ability to set control experiments does not correlate significantly both with the variables of proposing tests and formulation of hypotheses. When their responses under this category were further analysed, it was found that 38 p. c. to 46 p c. of the students failed to distinguish between stating hypotheses and their testing under controlled conditions by choosing one variable for isolation every time for they reworded or rephrased the same hypotheses. For example, water will flow more because the tube is long. Further, only 26 p. c. to 28 p. c. of the pupils could propose one experiment, 22 p. c. to 24 p. c. propose two experiments and 4 p. c. to 6 p. c. propose three experiments. Whereas no body could propose four experiments on the simple pendulum problem, 6 p. c. of the pupils were able to do the same on the beaker problem. No body could suggest control experiments for isolating the fifth and sixth variable. Here our finding does not support Piaget because according him, adolescents are not only able to suggest hypotheses freely but are also able to test them through control experimentation. This finding is further strengthened, as already mentioned on the four digits problems, the adolescent pupils are not in a position to tackle the said problem systematically by exhausting all the possible combinations. ***The major conclusion of this study is that the minds of fifteen year old pupils, even being a select group studying science, do not become fully experimental.***

6. Factor Analysis

At a later stage, it was thought desirable to analyse the mathematical structure of the problems used in this study, the available technique being factor analysis which attempts to reduce a matrix of inter-correlations among test scores and other variables to a minimum number of psychological factors accoouting in the process for the wide variety of individual performances. It became possible to obtain two forms of factor loadings, namely, orthogonal and oblique. Both methods provided the same mathematical structure for the problems under study.

Factor Loadings after Rotation

(Orthogonal form)

S. No.	Variables	I	II	III	IV	V
1.	Intelligence	−0.0919	−0.114	0.1537	−0.7503	0.0802
2.	Home Adjustment	−0.6654	−0.2667	0.0154	−0.0388	0.2006
3.	Health Adjustment	−0.7969	−0.0401	0.2505	−0.1097	0.0638
4.	Social Adjustment	−0.8381	−0.1199	0.1381	−0.0050	−0.1700
5.	Emotional Adjustment	−0.8372	−0.0731	−0.1002	−0.0937	−0.0463
6.	School Adjustment	−0.7442	−0.0996	0.1434	−0.0395	−0.2907
7.	General Adjustment	−0.9132	−0.1593	0.1086	0.0290	−0.0920
8.	Newness of the Problem	−0.0012	−0.0625	0.0337	−0.0011	0.8300
9.	Understading of the Problem	−0.5937	−0.2463	0.0972	0.4079	−0.4473
10.	Felt difficulty of the Problem	−0.5380	−0.0454	0.2325	−0.2383	−0.4139
11.	Confidence in the Problem	−0.4454	−0.3013	0.4665	0.3695	−0.4509
12.	Interest in the Problem	−0.3247	−0.1170	0.4685	0.4925	−0.2508
13.	Using two digits at a time	−0.5241	0.4505	−0.1644	0.3407	0.0321
14.	Using three digits at a time	0.1627	0.6084	0.0297	−0.0408	−0.2293
15.	Using four digits at a time	0.0995	0.8232	0.0925	−0.0868	−0.0684
16.	Formulating Hypotheses	−0.0369	0.0083	0.8954	−0.0799	0.0108
17.	Setting up Control Experiments	−0.1158	−0.4794	0.3035	−0.0243	−0.1849
18.	Framing Questions	−0.1218	0.2626	−0.1060	−0.6866	−0.3753
19.	Proposing Tests	0.1338	0.2202	0.3515	−0,1200	−0.5942

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Interpretation of Factors

First Factor : General adjustment has the highest loading (.9132) on this factor. The other loadings immediately following this loading in terms of size are .8372, .7969, .7442 and .5652. These loadings are on social, emotional, health, school and home adjustments respectively. Loadings of other variables are small and can be ignored. Hence this factor is hypothesized as *General Adjustment.*

Second Factor : The highest loadings on this factor are .8232, .6084 and .4504 which relate to variables : Using four digits at a time (seeing the problem as a whole), Using three digits at a time and Using two digits at a time. The loadings of other variables on this factor are non significant and hence can be neglected. This factor is, therefore, interpreted as ***ability to see the problem as a whole,*** It supports one of the basic notions of Gestalt psychology, that is, the problem is first seen as a whole before it is further analysed or later on synthesized.

Third Factor : The highest loading on this factor is .8954 which is on the variable : *formulating hypotheses.* Other loadings immediately following it are .4685 and .4665 which are on variables : Interest in solving problem, and Confidence in the problem. This factor comes out separately, distinctly, and dominantly It also supports Piaget's basic notion that children beyond the age of 11 years set up all sorts of hypotheses.

Fourth Factor : Here, the factor loadings become very very intriguing. The following loadings: −.7503 and −.6866 are highly negative which relate to the variables of intelligence and framing questions of that type whose answers pupils do not know. The highest positive loadings are ·4925, ·4079 .3695 and ·3407, which relate to the following variables; Interest in solving problems, Understanding of the problems, Confidence in the problems, and Using two digits. The loadings of Felt difficulty of the problem on immediate presentation is similar in sign as those of the loadings on intelligence and framing questions. In this context, the first three positive loadings can be considered plausible because these are very essential in an untypical situation like the one in which we have placed our students. Answering the problem straight away is difficult because only these questions are to be asked whose answers are not known to them.

This puts each of them in a very tight situation. Hence this factor can be interpreted as ***Interest in Generating difficult problems.*** But this factor does need to be confirmed by using an individually administered ***Piaget*** type test.

Fifth Factor : Here, the highest loading is ·8300, which is on variable : Newness of the problem. Scoring on this variable was reversible. So the negative loadings on understanding of the problems and confidence in the problem are explicable. So is the factor loading on the Felt difficulty of the problem. In whatever way the various loadings are looked, loadings on the Newness of the problem is very distinct and high. Hence, this factor can be interpreted as ***Newness of the Problem.***

Taking an overall view, it is strange that General adjustment rather than General Intelligence appeared as the first factor, It is an unexpected finding. The reason for this may be that it is a select group of students given science on the basis of their attainment in science in class VIII. However, Seeing the problem as a whole and Formation of Hypotheses can be considered two significant determinants of intelligence which appeared as the second and third factor respectively. On the fourth factor, the whole situation became quite intriguing because Intelligence acquired the highest loading but negative in sign. The next highest loading but negative in sign is another interesting variable : Framing questions—Problem, whose answers students do not know. The other highest positive loadings are on Interest in solving problems, Understanding of the problem, and Confidence in the problem. It is not an ordinary run of the situation in which intelligence instead of solving the problem tries hard to formulate difficult problems in search of answers, later on. Therefore, in case of problems, which are solved over a wide range of intelligence, a strong personality factor is suspected which may be akin to sensitivity to problems in creativity tests. It is, therefore, suggested that a large number of factorially known tests must be included in a study of this type in order to pin point the various hypothesized factors. It can, however, safely be added that the mathematical structure as indicated in this type of study is quite plausible for it comprises : General Adjustment, seeing the problem as a whole, formulation of hypotheses, interest in Generating problem and Newness of the problem.

Lastly, the top and the bottom group differed from each other at 5 p. c. and 1 p. c. level in respect of emotional adjustment. On other four measures (home, health, social and school adjustment), no significant differences were obtained.

Limitations of the Study

The following were the limitations of the present study :

1. The size of the sample (N=50) is small and drawn

from one school. However, within the restricted age range (15+), grade X raw score on intelligence test varied from 32 to 86.

2. The errors committed during the problem solving were not studied.

3. The reliability and validity of the problem solving tests were not determined because the basic notions under study were developmental rather than psychometric.

4. Role of hints and cues during problem solving was not studied. But, at the same time, the meanings of difficult words contained in problems were given individually when asked.

Study No. 6

The Formulating and Testing of Hypotheses During Adolescence

Purposes of the Study

The purposes of the study were :

1. To determine the relationship between the scores on intelligence and the scores on exclusion of variables.
2. To determine the relationship between age, grade and the scores on exclusion of variables.
3. To point out the main educational implications based upon the findings of the study.

Hypotheses

The hypotheses formed for the study were :

1. There is no significant differences on the mean scores of intelligence test and the scores on Exclusion of Variables between the top group and the bottom group.
2. There is no significant correlation between the grades and scores on Stating Hypotheses.
3. There is no significant correlation between the grades and scores on Testing Hypotheses.

Plan and Procedure

100 students of class VIII, Class IX, class X and class XI(25 from each class) of Demonstration Multi Purpose High School, Regional College of Education, Ajmer were taken as sample. The students were day scholars and of average

socio-economic status belonging to urban areas. The age range of the students were 12^+ to 17^+.

Administration and Scoring of the Intelligence Test and Stating and Testing Hypotheses Questionnaire

The administration of intelligence test and both the questionnaires was done in their respective classes one at a time. The time for intelligence test was given as mentioned in test manual and the time taken by students for both the hypotheses ranged from 30 minutes to 45 minutes.

The scoring on Intelligence test was done as directed by manual.

In stating hypotheses, the total number of pupils emitting a particular hypothesis for all was found out and arranged all those hypotheses in the descending order. All the pupils were arranged in the descending order meaning the pupil giving the smallest number of hypotheses coming at the top and the pupil giving the highest hypotheses coming at the bottom. The number of error in each hypothesis were determined and then co-efficient of fluctuations.

The scores given to test the hypotheses of each problem are :

0 —Wrong answer
1 —Just describes
2 —Partly describes, and
3 —Complete right answer

Main Findings and Conclusion

1. Except few fluctuations here and there, the mean performance of all the problems show an increasing trend in stating and testing hypotheses with grade.

2. All the problems are strongly correlated with each other. It is so because they measure more or less the same intellectual structure.

3. Using the Guttman Technique as suggested by him in ascertaining the undimensionality thought, the same was used to determine the coefficient of fluctuations in their thought processes. The values of these coefficents show that pupils show vast individual differences in abilities related to stating hypothesis.

4. Using the top 25% and bottom 25% groups, it was seen that they differ significantly from each other in respect to the variables age and grade. However, they did not differ on intelligence. The reason for this appears to be that intelligence test is used as one of the admission tool. Those who get below the certain score are not offered admission.

Study No. 7

Some Aspects of Concept Formation and Intellectual Development

Introduction

The central function of education and, particularly, science education is concept development while interacting with the environment, it is seen that pupils show vast individual differences in their ability to form concepts. The same is equally true when it comes to the application of the concepts formed to the problematic situation unknown to them. Here Piagetian system has a direct bearing on the conceptually based research in Science Education. The Piagetian model of intellectual development indicates that each student must enrich a conceptual scheme in a manner appropriate to his present stage of development. According to Piaget, there are two processes, namely, adaptation (accomodation and assimilation) to the environment; and the organization of experiences through action, perception reflection, other cognitive abilities, of course, not excluded. If the teachers are aware of how the house of intellect develops in the child, they will be in a better position to train children in the processes of thinking leading ultimately to the development of fundamental scientific concepts. The teaching and learning of science may then become more meaningful.

The Process of Concept Formation

It is necessary to consider the nature as well as the

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functions of concepts against the back drop of thinking for they are gradually 'built up' 'learnings' about our environment. According to Smoke, these are characterized by 'consistency of differential, generalized and symbolic response' This shows that little is known about how children form as well as utilize concepts. However, there are some ideas which do sum up superficially how concept formation takes places. We live in the physical as well as the psychological world. Several stimuli comprising objects, events, cues and people impinge on us and we are compelled to classify or categorize them on the basis of attributes. The presence of a particular attribute shows that it is a discernible feature of that object not at all shared by the other object. Concepts thus permeate our thinking. The child verbalizes, generalizes and discriminates in a wider frame of reference. This is a gradual affair because of the lack of linguistic ability. When the child is able to coordinate his movements with Language, he is pretty fast in the formation of concepts. Thus, he is in active commerce with his limited environment and goes on building his own coinages of explanation in the midst of satisfying experiences, annoyances, successes and failures.

Certain abilities come naturally to the growing child. Ability to conserve a stable conceptual structure appears only within the age group of 11 years together with classification, seriation and other operations necessary in the formation of number concepts. Concepts, generally speaking, widen and deepen throughout life. Abstract concepts like atom, gene, truth, beauty, goodness and sin etc. are difficult to acquire. Positive instances confirm concepts and negative instances bring out the anomalies in them for reconciliation including their rejection if warrented by the situation. With or without guidence, children form those concepts first which are of most use to them. According to the Geneva school, action is the basis of thinking. Sherrington went to the extent of saying that our present day mind arose out of sheer initial motor act.

Past Work

Concept formation in itself constitutes a major area of investigation. When other outside variables are included, amounts to getting an extra known from an equation connected by two unknowns. The work of Piaget has led to descriptive analysis of basic, physical, logic, mathematical and moral concepts from birth to adolescence. Very little work has, however, been done on the evolution of concepts in relation to their functional and quantitative aspects. Chronologically speaking, Inhelder B and Piaget J (1958); Elkind D (1961); Lovell K and Ogilvie E (1961); Hull C.L.; Smoke, and Haufmann (1961); Bruner J.S. Goodnow and Austin (1962); Uzgiris I (1964); Kofsky E (1966); Farrell M.A. (1969 ; Ginsburg H and Opper S (1969); Karplus and Peterson (1970); Higgins T.A. Gaite A.J.H. (1971); Kohlberg and Gilligan (1971); Mc Kinnon J. W. and Renner J. W. (1971); Towler J. O. and Wheatley G (1971); Papilia D. E. (1972); Renner J. W. and Stafford D. G. (1972); Hobbs E. D. (1973); Nadel C & Schoeppe A (1973); Chiappetta E. L and Whitefield, T. D. (1974); Docherty E. M. (1974); Graybill (1975); Bates G. C. (1975); Sayre S and Ball D. W (1975); Lawson A. E. and Blake A. J. D. (1976); Joyce L. L. (1977); Luis L. C. and Dudley H. J. (1978); Warrent T. W. and Lawson A. L. (1978) have done considerable work in this area. At home, workers like Joshi D (1963); Joshi J. N. (1970); Bevli U. K. (1978) have also investigated certain aspects of concept formation.

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At the Regional College of Education, Ajmer, several workers have investigated the varied aspects of concept formation, Problem solving not excluded, with special reference to Science Education. A few studies to mention in this context are : The Growth of Logical Thinking Using Piaget Type Task (Vaidya), The Exclusion of Variables or Formation of Experimental Mind (Leela Kansakar, Madhu Mathur and Padmini M. S.) Study of Physical Science Concept Formation (Ann Jacob) and A Factoral Study of Adolescent Thought Loaded with Scientific Contents (Sandhu T. S.). All the above mentioned studies indicate :

(i) Concept development is influenced by the characteristics of the learners, individual tasks and environment. The role of each variable in concept development is yet to be studied in its widest variations over a sufficiently long time.

(ii) Sex differences in concept development need explicating for they may have educational implications especially for the girls.

(iii) Age based stage as propounded by Piaget is contradicted in general but the sequence of development however remains invarient. The role of hints and cues or precisely speaking, teacher intervention is likely to remain ununderstood for sufficiently long time despite the availability of high speed computers.

(iv) Factoral studies in this area are urgently needed. Also are needed studies which trace the growth of some fundamental scientific and mathematical concepts.

The Study

The present study aims at investigating the following purposes :

(i) To see how concept formation takes place in children on certain selected concepts.

(ii) To determine the relationship between the physical science concept formation and intellectual development.

(iii) To determine the relationship between the intellectual development and achievement in science.

(iv) To point out the main educational implication based upon the findings of the study.

Hypotheses to be Tested

It is proposed to test the following hypotheses—

(i) There is no significant difference as judged by the scores in classification ability, proportional reasoning, conservation of liquid, academic achievement, attainment of selected physical science concepts and total scores obtained in Piagetian task between high intelligent and low intelligent pupils.

(ii) There is no significant relationship as judged by the scores between physical science concepts and achievement in science, physical science concept and total Piagetian tasks, intelligence and achievement in science.

Method of Procedure

The sample for the present study consisted of 100 students, 20 each from classes V, VI, VII, VIII and IX of demonstration multipurpose school, Ajmer, within the age group of 9+ to 13+ years They came from average socio-economic status and belonged to the urban area. The tools for the study comprised intelligence test (Ravens Progressive Matrices), a battery of three Piagetian tasks : conservation of volume, classification and proportion and some fundamental concepts in science like area, density, force and pressure. The language difficulty of the questions was intentionally kept low. Both the tests carried fifty marks each. After the pilot study, the various tasks were administered to a group of 20 students at a time.

Main Findings

The main findings of the study indicated :

(i) The means on conservation, proportion, classification area, density, force and pressure show increasing trends with grade. This was an expected finding.

(ii) There is a dip in some of the grades, on the schemes of conservation, classification, density, force and pressure. Hump effect is suspected.

(iii) There is noticed wide variation in Piagetian schemes of thought than in specific scientific concepts.

(iv) The top group in contrast to the bottom group is more or less homogeneous in performance on the variables of intelligence, achievement in science, selected science concepts and Piagetian tasks.

(v) There are insignificant correlations among achievement in science, some selected physical science concepts and Piagetian tasks.

(vi) The scheme of proportion in contrast to scheme of classification develops later i. e. below the age of 13 +. The high I. Q. and the low I. Q. groups however, did differ on scheme of conservation, Piagetian tasks and the acquisition of physical science concepts.

Educational Implication

Jean Piaget has frequently said that he is little interested in children, psychology and education etc. If his entire work is considered the following educational implications appear :

(i) He emphasizes the importance of activity in the growth of intelligence.

(ii) He explores in depth the growth of the child's thinking in relation to certain universals in the contents of human experiences such as the nature of objects, space, time, motion, chance, causality, moral responsibility and social awareness.

(iii) He proposes that certain underlying pervasive logico-mathematical structures are found repeatedly in these diverse areas. Taos, Paris (Pleasure of discussion) Athens (the Socratic method) and Eldorado are the four models worthy of consideration while schematizing the use of materials and exercises on the one hand and the type of social relationships on the other.

In the context of the present study, it can be safely considered that children should be allowed to handle abundently the processes of thought rather than the products of thought for which the use of materials and experiments can be quite handy. The children also need to be trained in handling, their erratic responses through exchange of ideas. that is, they need no longer remain egocentric in their intellectual behaviour. It is yet to be seen how far the deficiencies in Piagetian thought as manifested by children can be a handicap in mastering abstract concepts. Here Piaget provides a deeper model because it is through action as well as reflection on actions that the real knowledge is born in the mind of individual children.

Study No. 8

The Formation of Experimental Mind During Adolescence

Introduction

The Geneva school under the leadership of Professor Piaget has been a mine of exciting ideas, which compells one to see the usual developing phenomenon of human thought afresh unconventionally through the use of a semi objective method of critical exploration called the Method clinique. According to him, logical thinking or intelligence develops in stages which depend upon each other. Each stage is defined both by its qualitative as well as quantitative characteristics, thus, clearly distinguishing between child thought and adult thought. In his entire work extending over sixty years or so, the basic concept of hypothesized mental structure (a sort of blue-print) is constructed and reconstructed from infancy to adolescence which guides individual's intellectual behaviour. He further introduced the term OPERATION (interiorized action) which attempts to explain the entire course of developmental stages. It as well modifies the object of knowledge. Moreover, it is always linked to other operations and is consequently a part of total structure. Thus, he considered these operational structures as the basis of knowledge and succedeed to distinguish four main stages of intellectual development, namely, sensori motor (0-2 years); pre-operational (2-7 years); concrete

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operational (7-11 years) and formal operational (11-15 years). It is at the last stage that the adolescent pupil is in a position to speculate over possibilities rather than sticking to the realities of the situation, employ combinatorial system and propositional logics of conjunction, disjunction, negation and implication. In the context of the present study, it is to be observed whether the adolescent pupil is in a position to state and test hypotheses, when several test situations inhering this variable are presented to him.

Purpose of the Study

The present study aims at investigating the following :

(a) To determine relationships among scores on stating hypotheses, testing hypotheses and achievement in science.

(b) To look for varied patterns of responses leading to the formation of experimental mind,

(c) To explore the hump-effect, if encountered.

Hypotheses Proposed

It is proposed to test the following hypotheses :

1. Ability to state hypotheses, test hypotheses, exhaust hypotheses and interest in problem solving does not increase with grade,

2. There is no significant relationship between the total scores on the Piagetian tasks and achievement in science.

3. Adolescent thought is not wholly influenced by the content of the problem.

4. Errors committed during problem solving do not increase with grade.

Method of Procedure

The sample for the present study comprised of 120 pupils in all, 20 each drawn from grade VI to XI of the Demonsration School under the control of the Regional College of Education, Ajmer. The age range of pupils varied from 11^+ to 16^+. Experimental problems were demonstrated to the pupils in the class. But they were not expected to record the observations. The three sets of questionnaires aimed at measuring (1) stating hypotheses; (2) testing hypotheses; (3) combinatorial grouping and (4) grasping the essence of the problem. All the responses emitted were the written ones which were scored at three levels depending upon their speciftcity, aggregation and complexity.

In short, using the questionnaire approach, the variable under study, is studied in its maximal variation through a series of diverse problems as suggested by Piaget but not yet done by a single worker in to-to.

Brief Description of Problems Used

Several problems in closely allied contexts were used which when classified resulted in four distinct variables, namely, stating hypotheses, testing hypotheses, exhausting all possibilities and grasping the essence of the problem. The varied processes of thinking underlying them sufficiently sampled the formation of experimental mind. Now consider the brief details of the problems used in this study.

S. No.	Variable	Problem	Illustration	Scoring	Maximum score
1.	Stating and Testing hypotheses	(i) The flow of water through a tube problem	Name all the factors on which the quick filling of the empty beaker depend	One mark for each response	open 2
		(ii) The simple pendulum problem	Suggest control experiments.	One mark for each suggested experiment	2
		(iii) The ramp problem.			2
2.	Stating hypotheses	(iv) Seed problem.	Name all factors which make the seeds grow into healthy plants	One mark for each response	
3.	Testing hypotheses	The worm problem	Predicting the movement of worms under moisture and light	One mark each for correct response	2
			Also suggesting an additional experiment	Three marks for suggesting additional experiment	3
4.	Exhausting possibilities	(i) Digital problem	Make as many figures as possible out of 6,7,8 and 9.		

S. No.	Variable	Problem	Illustration	Scoring	Maximum score
			(a) Using 2 digits at a time	One mark for each combination	(a) 12 marks
			(b) Using 3 digits at a time		(b) 24 marks
			(c) Using 4 digits at a time		(c) 24 marks
		(ii) The magic seed problem.	Exhaust all the possible aggregated combinations of water, fertilizer and sunlight.	One mark for each combination	27 marks
5.	Formulating questions questions (Problem sensitivity)	Cycle problem	Suggesting problems only whose answers they do not know.	One mark for each acceptable question posed	open
6.	Grasping the essence of the problem	Questions inviting wrong answers intentionally	A stick is 10 cm. long. It is cut an inch per minute. How many minutes will it take for it to be cut into 1 inch pieces ?	Zero marks for wrong answers. One mark for correct answer	

Illustration of the Phenomenon

Show the experiment on 'Flow of Water Through a Tube' under pressure to the adolescent pupils, one at a time. Then raise the following questions :

(i) On what factors does the collection of water in the beaker B depend ?

(ii) How will you study the influence of the following factors or variables individually : the length of the glass tube, size of the hole and the level of the water.

The children below the age of seven fail to specify the above mentioned factors or variables. They also fail to set-up control experiments. At the immediate higher stage, they describe the experimental set-up and, generally speaking, do remark that water passes through the tube. They are also seen to make comments. Consider the following responses which they make while trying hard to solve this problem :

1. It is not necessary to use this apparatus. You are going to collect water. Why not use syphon ? You take a longer or smaller tube in length, I see that the water flows from a higher level to a hower level.
2. Use a right-angled tube.
3. Do you see air bubbles ?
4. Be careful that the tube is not slanting.
5. You see the hole is there, otherwise how can water flow ? You see that the clean water is coming out. The presence of water is very essential in this experiment.
6. What is the weight of a beaker ?
7. What is the length of the glass-tube ?

The children are also found :

1. Reproducing the question partially or fully in writing, repeating the question orally, trying to collect water.

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2. Supplying the information like : This is a beaker or a glass-tube. The beaker is round. The glass-tube is 15" long. Giving a formula and method not needed in the problem.

3. Playing with the experimental material.

They give these responses which have no business to be there. They point out to certain things (air bubbles) suggest a way out of the problem, give and demand information which is not required, and even go to the extent of reproducing part of the question. These are known as arbitrary errors. They can be educated out of this only if they sufficiently interact with the material over a certain length of time. According to Piaget, they behave this way because their basic concepts in relation to the problem under study have not yet developed.

Consider the following response given by a pupil of Class VIII (under 15 years). Remarks by the experimenter are placed in brackets or a bit away from the running text.

Looks thoroughly at the experimental set-up. Then says : Water is coming out of the larger beaker into the smaller beaker You know that water always flows from a higher level to another level. Hesitates for some time and then says :

Length is important.

It no length, no water will be collected. Laughs because the problem goes.

I mean length can change.

No, I mean hole.

It can be small, medium and big.

if the hole is larger, water level in the larger beaker will fall quickly.

Can show you this, if you so wish

(No, you need not)

The problem is how I can show this to you.

I will proceed as follows :

Take two tubes.

(Yes, you are correct)

If I have the large tube and fix it there, water will come out.

(Yes)

If I fix the smaller one, the water will come out a bit soon. There is going to be small difference in time. So smaller the tube, sooner the water will come out. (Now thinks ! Then says that my problem is to find out whether length plays an important part in the amount of water collected).

Give me some time. Asks : What is this ?

(This is a watch. I have told you earlier).

I am a fool because the water has to come out of the two glass-gubes, Now, I think I can solve the problem like this.

If longer tube gives more water to the collecting beaker, then I can say that length is an important factor. If amount is the same, then length has nothing to do here. Similarly, he gives an experiment for isolating the factor of hole. Now he comes to the end of his wits. If I increase the size of the hole, the level of water falls down immediately. If I take the other tube (with a smaller hole), it takes time for the water to go. Level of water falls down slowly and slowly. Water level fell in other experiments as well (while isolating the factors of length and hole).

Thinks ! Plays with his pencil. I think this factor has nothing to do because water falls down any way. I think the first two factors are important.

What does the above record show ? It shows that the pupil commits arbitrary errors as he goes along with the problem. He observes anything interesting which provides false lead (level of water fell). He finds sense in his observation in the process of linking this observation with other observations. He is able to identify two variables and succeeds ultimately in suggesting two control experiments. The third variable level of water is missed by him. The lesson of this exercise is that teachers should develop sensitivity as well as respect for pupils' thought when they carry out individual dialogues with children who vary in intelligence and achievement. It is through a path somewhat similar to this that he reaches fairly well the formal stage in which possibilities rather than reality dominate his thinking.

Formal Stage

There is a distinct difference between the concrete and the formal stage. At the former stage, all intellectual efforts expanded and intensified on horizontal plane. Extent of thought was firmly tied to the concrete situation and was verified or even tested within the context of the experimental situation. But, at adolescence, thinking goes beyond the immediate present, and attempts are made by the adolescent pupils to establish as many vertical relationships as possible. Notions, ideas and concepts are formed which belong to the present and future. All sorts of hypotheses and possibilities are considered and their implications deduced and tested for relevance or irrelevance. Minute details are not at all ignored. At about the end of this period, the adolescent pupils manifest maturity of thought for they can use symbols in their operational thinking, In short, they think by applying symbols of thinking or to put in other words, they develop concept of concepts, a sort of second and third order reflections.

To illustrate, it is at this stage that the adolescent pupil is about to develop a highly logical answer, as shown by the following reply to the same experimental problem already posed.

> *I can see the factors. These are : length of the tube, size of the hole and the level of water in the large beaker. For the first factor, I will take three glasstubes of different lengths but their holes should be of the same size. I will also keep the level of water same, before starting the experiment. In each of these three cases, I will collect water exactly for 10 seconds. What I mean is that the time should be kept— constant, now I have to make a judgement. In case, the amount of water collected is the same in all the three cases, I can conclude the length of that the tube is of no consequence. If amounts are different, I can make my judgement accordingly. The influence of the other factors can be found out similarly.*
>
> *OR Let me think ! (Thinks) I am supposed to setup the experiment in such a manner that I keep two factors the same except the one whose influence, I wish to judge. I need :*
>
> *(i) Three glass-tubes of different lengths but having similar holes (Meant size)*
>
> *(ii) Three glass-tubes of the same length but of different holes.*
>
> *(iii) Water level can be adjusted.*
>
> *Then he sets up an experiment to suit the requirement of the problem.*

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Main Findings

Subsidiary findings being numerous, the main findings of this study indicated :

1. The mean performance on problems included in this study shows an increasing trend with age which, of course, is an expected finding.
2. There is a significant correlation between the total scores on the Piagetian tasks and achievement in science at .01 level of significance.
3. Adolescent pupils, particularly speaking of lower grades, contrary to Piaget, are attracted more by the content rather than the form of the problem.
4. The tendency to exhaust possibilities of combinatorial type, contrary to Piaget, increases with grade only and becomes fully operational during the last phases of adolecence only.
5. Errors committed during problem solving do not fall linearly from grade to grade but show fluctuations which decline only after suffering a hump (bihumps and tri–humps too).

Prof J. S. Bruner called them "Growth" errors, which arise when the adolescent pupils use a risky rather than a well established strategy.

The possibility of this phenomenon was hypothesized by N. Vaidya in the case of adolescent pupils who were at the transitory stage of mental development, that is, between the concrete stage and the formal stage. The study of relevant research literature show that this view of seeing the data had been missed by the earlier workers : Piaget, Inhelder and Bruner. The same phenomenon also appeared in the doctoral studies of T. S. Sandhu and Padmini M. S. When not looked for it, it also appeared in the present study on another variable : stating hypotheses as well. All this goes to show that hump effect is diversely contextual in character.

6. In continuation, it appears, in other words that stating hypotheses could appear at the concrete stage and testing hypotheses alone well past the mid-adolescence.
7. This point of view is further strengthened when it came to suggesting additional experiments based on experimental data presented pictorially needing no mathematics at all.

Educational Implications

Where as Piaget used to say frequently, I am not interested in Psychology, Education and Children, his work did lead to deeper implications for day to day instruction. Education for understanding through self-activity and reflection, seeing and analysing others view points, assimilation rather than accomodation, mastery of research operations and working on cooperative projects are some of the distinguishing characteristics of the Piagetian education. Children should strive hard to achieve the distant goals for they have to lure longer lines than their teachers who may focus on short term goals of instruction. The Karplus cycle comprising exploration, invariation and discovery makes education joyful for the youngesters.

For the adolescents as well as the adults, the following four approaches further appear :

1. *Taos*—respect for the individual artisan, abundance of semi-structured instructional and illustrative materials drawn from diverse field of knowledge.
2. *Paris*—Pleasures of discussion between equal partners.
3. *Athens*—as reflected in the Socratic method.
4. *Eldorado*—as reflected in inquiry and discovery methods.

Lastly, his work, informs teachers intuitively, how to act decisively through the museum of defects for they will through experience come to know that human mind react to concrete and abstract ideas at different levels of intellectual development implying thereby that more and more inputs in education may not lead to more and more astounding results for viceversa may even hold true in the Genevan context. So, in the name of modernization, if any country simply down grades the content, it is bound to generate allergies all round within its borders of the basic Piagetian essence, because of the transmission of mental structures mechanically rather than reflectively spin off advantages for everybody await around the corner if one tries to care to turn one's gaze on the Genevan school, so laboriously built by the Genevans. The world need no longer pass by as usual for it is the business of the human mind to go on creating novelties, each more noveler than the other.

Study No. 9

A Study of Relationship Between Hypothesis-Testing Ability in Science and Creativity

Introduction

Hypothesis-making and hypothesis-testing abilities are considered as important stages of higher mental processes. Dewey (1933) has categorised these two abilities as the third and fourth stages in a five-step process of reasoning and thinking namely, awareness of the problem; collection of facts needed to solve it; formation of hypothesis or possible solution; evaluation of the hypothesis against the facts collected; and verification. Kuhlen (1986) says that the process of concept development is an active process of hypothesis-forming and testing of self-discovery.

Hypothesis-making and testing abilities of a person play an important role in problem solving. Productive thinking was stressed by Wertheimer (1945) who emphasised the point that "our methods of pedagogy are likely to encourage learning by rote rather than by understanding the situation. The children applied the learned formula to situations where it did not make sense and were unable to see applications to a novel variation of the original example".

This research was conducted with a view to studying the Hypothesis-Testing Ability (HTA) of the students which forms an important aspect of productive thinking. The HTA scores were then related to the creativity scores obtained by the students. It was the assumption of the investigator that if the student employs varying methods and techniques in the solution of a scientific problem he should also score high on the general test of creativity. The following hypothesis were tested for this purpose :

(1) Creativity scores will be correlated significantly with the hypothesis–testing ability (HTA) scores in science.

(2) The scores on contributory determinants of creativity (i. e. flexibility, fluency and originality) will be correlated significantly with hypothesis-testing ability (HTA) scores.

Method

Subjects

The study was conducted on randomly selected 156 eleventh class students, 109 boys and 47 girls, drawn from five higher secondary schools of Bhopal city.

Tests

Two tests were used in the study. One was the verbal test of creativity developed by Baquer Mehdi (1973) and the other test, Hypothesis Testing Ability Test (HTAT), was developed by the investigator. Mehdi's verbal test of creativity has six sub-tests measuring the three creativity factors of frequency, originality and flexibility. The test is used to measure the creative talent at all stages of education excepting the elementary stage. Its test-retest reliability is ·96 and the indices of validity range from ·26 to ·40 for the three sub-variables of creativity.

Hypothesis-testing ability test (HTAT) is assumed to give an index of hypothesis-testing ability of a person which is operationally defined as the ability to provide a number of possible solutions to a number of scientific problems. HTAT was constructed by writing 15 problem statements covering different areas of science viz., Biology, Physics, Chemistry and Arithmetic. The problems were screened by a panel of science teachers for content-analysis. Some of the problems were rejected on the basis of their difficulty and ambiguity in language. Others were dropped because they required a very specific knowledge (achievement oriented) of the subjects and did not generate problem-solving behaviour. As such one practice exercise and ten problems were finally retained from different areas of science. Examples of specimen items from Physics and Arithemetic are given below :

Problem I :

Different metals have different conductivity of heat. What experiments can you conduct to test this proposition ?

Suggested solutions

(i) This can be done by putting the metals in a box containing water with portions of the metals projecting outside. The metals are coated with wax. By heating the box, the wax starts melting at different times.

(ii) Take any metal box in which handles of different metals are attached. Heat the box and note which of the handles gets heated first.

(iii) By obtaining their specific heats.

(iv) Other solutions with minor modifications.

Problem II :

Given 2, 5, 6, 9, 11 and 12. Obtain sum 8 in different possible ways by combining any number of given numbers using the four arithmetical operations (+, −, ×, ÷). You cannot use one number or one operation twice in the same solution.

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Suggested solutions

(i) $6+2=8$

(ii) $9-6+5=8$

(iii) $9+5-6=8$

(iv) $11-6\div2=8$ etc.

Tests of creativity prepared by Guilford (1966), Foster (1973) and Mehdi (1973) were consulted while preparing HTAT. But the hypothesis-testing ability test is different from the general creativity tests in the sense that it includes subject-based problems. Each proposition could be solved in a variety of ways. The students were required to indicate as many possible ways, as they might think, in which these problems could be solved.

Data Collection

The data were collected by administering tests to students of five higher secondary schools. Subjects (N=156) were given 10 problem-statements and were required to give as many solutions of the problems as they could. One practice exercise titled 'barometer story' was given to the students. No time limit was prescribed but the test was completed in about 45 minutes by most of the subjects. Verbal test of creativity took about one hour to complete.

Scoring and Data Analysis

In HTAT a credit of 2marks was given for providing one reasonably sound solution. A student could suggest any number of solutions. There was no limit of maximum scores. The scores, however, ranged between 7 and 30. All the subtests of creativity were scored for fluency, frequency and originality factors. Unusual responses were noted and scored according to the criteria given in the test manual. Raw scores obtained in both the tests were converted into T-scores separately For creativity test a composite score was also determined.

Results—

Product-moment correlations were calculated for finding the relation-ship between the scores on creativity tests and HTAT. The results given in *Table 1* do not indicate a significant relationship between HTA and flexibility $(r = .07)$ factor and also between HTA and overall creativity scores $(r = 0.11)$. However, the remaining correlations namely between HTA scores and fluency scores $(r = 0.46)$ and originality scores $(r = .27)$ separately are both statistically significant $(p < .01)$.

Table 1

Showing Correlations Between the Hypothesis-Testing Ability Scores and Various Creativity Scores in Order of heir Magnitude.

Rank Order	Variables	r
First	HTA and Fluency	0.46*
Second	HTA and Originality	0.27*
Third	HTA and Composite Creativity	0.11
Fourth	HTA and Flexibility	0.07

*Significant at .01 level

Discussion

Though HTA has been found to be highly correlated with two of the three sub-factors of creativity viz fluency $(r = 0{\cdot}46)$ and originality $(r = 0{\cdot}27$, it is not so with the third factor i.e. flexibility $(r = 0.07)$. This, consequently lower the degree of relationship between HTA and overall level creativity $(r = 0.11)$. There can be many plausible explanations for these results. One reason could be the students instead of being encouraged to be flexible in their solutions to problems are being fed with conventional solutions given in their text books. It also appears possible that that the fear of being wrong makes the students give stereotype responses to scientific problems.

The present research has some implications for our day to day instructional work. Some problems should be suggested which can be attempted by different approaches. For example, various proofs of geometrical theorems should be incorporated in our text books so that the students may 'go beyond the information given'. If the students are encouraged to give varied solutions of scientific problems, this can possibly bring a corresponding increase in their capacities for becoming more flexible and fluent in their solution to scientific problems. The scope of this study can be further enlarged by comparing the HTA scores with non-verbal creativity test scores.

Study No. 10

A Study of Relationship Between Problem Solving Ability and Some Relative Personality Traits Using Piagetian – Type Tasks

Aims and Objectives

The present investigation was undertaken for the following purposes.

1. **To decipher the personality characteristics which are generally found associated with the problem solving ability of a child.**
2. **To cross validate the results of the present study with the results of similar studies on problem solving conducted earlier.**
3. **To find the contribution of the investigated personality variables in predicting the problem solving ability of children.**

Hypotheses Tested in this Study

The study aims at testing the following hypotheses.

1. **Reserved and detached children are better problem solvers.**
2. **Children with better power for abstract thinking (more intelligent) are better problem solvers.**
3. **Children with emotionally stable and mature personality are better on problem solving tasks.**

4. Undemonstrative and slodgy children are better on problem solving tasks.
5. Assertive and aggressive children are not so good in problem solving as are the obedient and mild children.
6. Sober and serious children have more problem solving ability.
7. Persistant children have more chance of having better problem solving ability.
8. Adventurous and socially bold children have better chances of developing their problem solving ability to the maximum.
9. Tenderminded children can better exploit their problem solving ability.
10. Zestfulness may not be of much help in developing problem solving ability in a child.
11. Apprehensive and insecure person may make better use of their problem solving ability.
12. Self sufficient and persons preferring their own decisions are expected to be better problem solvers.
13. Self-disciplined children seem to better exploit their problem solving ability.
14. Slightly frustrated children may make fewer error in their problem solving tasks.
15. Theie are no sex-differences in problem solving ability.
16. Problem solving ability increases with grade and age.

Sample

The sample comprised 74 boys and 79 girls studying in grades VII to XI which was drawn from two higher secondary schools and one middle school (co-education).

Variables and Tests Used

The Piaget type tasks comprised classification, grouping of thought, generalization, permutation and combination, ratio and proportion, formulating probing questions, interpretation and co-ordination of information, stating and testing of hypotheses, space visualization and grasping the essence of the problem. For collecting data on personality traits, the H.S.P Q. as developed by Prof Cattell was used.

Major Findings

The following findings appeared

1. Grade was found to be significantly correlated with scores on all types of Piagetian tasks except these relating to classification and grouping of thought.
2. Except on ratio and proportion, girls exceeded boys on all this tasks.
3. Persistence correlated significantly with classification, generalization (arithmetical and algebraic), formulating probing questions, interpretation and co-ordination of information and stating and testing of hypotheses.
4. Intelligence correlated significantly with all the types of Piagetian tasks.
5. Ergic-tension was found to be significantly correlated with such problem tasks as :
   (i) generalization with airthmetical and algebraic symbols.
   (ii) interpetation and coordination of information and
   (iii) visualisation.
6. Conformity was also found to be significantly correlated with three types of problem tasks:

(i) grouping of thought

(ii) generalisation with airthmetical and algebraic symbols and

(iii) space visualisation.

7. Tendermindedness was found to be significantly correlated with:

   (i) grouping of thought, and

   (ii) stating and testing hypothesis.

8. Undemonstrating personality was found significantly related to formulating probing questions; enthusiasm was found significantly relted to space visualisation and reflective personality was found to be significantly related to ratio and proportion.

9. The rest of the personality traits were not found to be related to any of the Piagetian type of tasks considered in this study in any significant way.

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Study No. 11

The Effect of Training on Formal Operational Thought : Stating and Testing Hypotheses

Introduction

Studies regarding the development of formal thought (Chiappeta and Collete, 1975; Dale, 1972; Higgings and Gaite, 1971; Jackson, 1965; Lawson and Blake, 1976; Martorano, 1977; Vaidya, 1964) show that in majority of cases the formal thought develops a little or do not develop at all upto the age of 15 years. Piaget (1972) has described that this may be due to the absence of inter-action of factors in different populations. This study was intended to collect emprical evidence whether the vital aspect of formal thought-stating and testing hypotheses can be accelerated through a training programme scheduled for exposing the adolescents to different problems which require formulation of tentative hypotheses and their verification under controlled conditions.

It is clear from the studies regarding the relationship between formal thought and intelligence (Khun, 1976; Sandhu, 1980; Vaidya 1964 Valentine, 1975) that two measures are significantly related with each other. Hence it was thought desirable to control the influence of intelligence in experimental and control groups.

Objectives of the Study

The experiment was planned keeping in view the following objectives :

1. To see the effect of training on the ability to state hypotheses.
2. To see the effect of training on the ability to test hypotheses.

Experimental Design

Matching groups design was adopted for this study. The experimental and control groups were matched with respect to the dimensions of stating hypotheses and testing hypotheses. The two groups were also equated with respect to the measure of intelligence. Pre-test-post-test technique was used to obtain data. The mean scores of the control and experimental groups regarding the dimensions of stating hypotheses and testing hypotheses on pre-test and post-test were compared through t-test technique.

Hypotheses

The following null-hypotheses were put to test :

1. There is no significant difference between the mean scores of experimental and control group on the dimensions of stating hypotheses on post-test.
2. There is no significant difference between the mean scores of experimental group and control group on the dimension of testing hypotheses on post-test.
3. There is no significant difference between the mean scores on pre-test and post-test of the experimental group on the dimension of stating hypotheses.
4. There is no significant difference between the mean scores on pre-test and post-test of the experimental group on the dimension of testing hypotheses.

Sample

Out of 140 students studying in IX and X class of a rural high school in Kurukshetra district, 80 students were selected for the study, taking the age range of 14+ to 15+ years only. The students were divided into the experimental and the control groups (N=40 in each) as per experimental design of the study.

Tools Used

(a) Jalota's General Mental Ability Test.

(b) Test of Stating and Testing Hypotheses. It consisted of two problems :

  (i) Pendulum problem

  (ii) Flow of liquid through a tube problem.

Procedure

The test of stating and testing hypotheses was administered as pre-test in the beginning along with the test of intelligence. After scoring, the students were divided into experimental and control groups which were matched with respect to the scores on the dimensions of stating hypotheses. The two groups were also equated on the measure of intelligence. The experimental group was given training regarding stating hypotheses and to test hypotheses under controlled conditions. The training period consisted of ten sessions.

Statistical Analysis

The mean scores of the experimental group on the dimensions of stating hypotheses and testing hypotheses on pre-test and post-test were compared using t-test technique.

Results

1. The difference between the mean scores of the experimental group and control group on the dimension of

stating hypotheses on post-test has been found to be significant at $< \cdot 01$ ($t = 3.806$).

2. On the dimension of testing hypotheses, the difference between mean scores of the experimental group and the control group has been found significant at $<.01$ ($t = 7.750$) on post-test.
3. A significant difference has been found between the mean scores of the experimental group on the dimension of stating hypotheses on pre-test and post-test $<.01$ ($t = 8.617$) level of significance.
4. The mean scores of the experimental group on the dimension of testing hypotheses on pre-test and post-test differ significantly at $<.01$ ($t = 10.00$) level.

Hence, all the null-hypotheses formulated were rejected in the light of the results obtained in the study. Thus, the opposite of each hypotheses stated earlier may be taken as a conclusion.

Conclusion

In general, it has been concluded that training has a significant effect on the development of the ability of stating hypotheses and testing hypotheses an important aspect of formal thought. Similarly the other constituents of formal thought can also be developed among the adolescents by exposing them to such training schedules.

Study No. 12

Conservation of Mass Weight, Volume and Concept Attainment in a Group of Indian Students Age 10^+ to 18^- Years

Introduction

The resurgence of interest in the study of "intellectual level of development" during last 20 years is reflected in the increased attention by "developmental psychologists" and the "Science Educators" have given to the acquisition of logical thought in the children and the development of curriculum in congruence with the mental structure of the children. The major source of impetus for it has been the work of Jean Piaget and his colleagues.

For Piaget, conservation is a central pre-requisite for the acquisition and subsequent development of logical thought. According to Piaget, "Every notion, whether it be scientific or merely a matter of common sense, presupposes a set of principles of conservation...." (Piaget, 1965). Piaget's contention is that conservation reasoning is a necessary condition of all rational thought "Conservation" concept is of theoretical interest because it reflects cognitive competence of some complexity, while the period of acquisition is the threshold to greater and more complex intellectual growth. In general, the conservation can be divided into two distinct types (Brainerd, 1970) :

(a) the so-called first order quantitative invariants (e. g., number, length, area, mass, weight), and

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(b) the so-called second order invariants (e. g., volume, density, momentum, rectilinear motion).

Piaget considers the first order conservation indices of concrete-operational thought and the second-order conservation indices of formal-operational thought. Researches into the development of Concepts of conservation have been followed with considerable interest by both Child Psychologists and Developmental Psychologists & a number of replication studies have been carried out by investigators in different countries (Elkind, 1961, 1962; Brainerd 1970; Dassen. 1977; Flavell, 1977; Inhelder & Piaget, 1958; Modgil & Celia, 1976; Graves, 1972; Lawson & Nordland, 1977; Lovell and Ogilvie, 1960; Renner, 1977; Vaidya, 1979; Jain & Upadhyay, 1978; Jain, 1980; Rao, 1976; Basu & Ramachandran, 1979).

The cross-cultural studies had clarified some of the epistemological and structural aspects of conservation in general and of conservation of physical quantities in particular. The information obtained about the student's conservation reasoning abilities is of great help for the teachers involved in selecting, sequencing and presenting the curriculum (Lawson and Nordland, 1977).

There is a growing awareness of Piaget's work in the construction of science courses, but as Belangar (1969) has indicated in reviewing learning studies in science education, there is a need of studies for investigating the fine structure and scheme structure for specific science tasks. Bart (1971) also emphasised that, "An individual who is capable of applying formal operational skills to tasks within a given content (e. g. semantic content) would be more apt to apply formal operational skills to other tasks within the same content than to tasks in a content in which the individual has not applied formal operational tasks. This hypothesis, if substantiated, would provide guidance to educators for the formulation of learning experiences for adolescents." Similar observations were reported by Lawson, Nordland and Devito, 1975; Lawson and Blake 1974; Blake, Lawson & Nordland 1976.

Further, Lunzer (1965) suggests that "tasks, though identical from the structural (logical) point of view, may differ in their complexity and in the degree of familiarity of the subject with the terms and ideas in the task. The most powerful reason for the comparative difficulty of tasks he suggests as being due to the degree of 'consonance or dissonance with previously existing notions.'' These ideas indicate, that the logical structure and familiarity with the terms, ideas of the tasks are the important reasons for the dificulty of task. The present study is also aimed to know, whether the conservation abilites are acquired in a specific order and to interpret the concept attainment by the students. The four Piagetian, "conservation tasks" were selected for the present study.

The major objectives of the present study were as follows :

(i) To determine the sequence of the conservation ability acquired by the students.

(ii) To analyse the tasks and to identify the various sub-concepts necessary for its correct performance.

(iii) To interpret the results in terms of the logical structure and the content structure of the tasks.

Subjects

A random sample of 15 boys and 15 girls from each of the class VI to XI, 50 boys and 50 girls from class X, 90 boys and 90 girls from class XI was drawn for the present study. These four hundred students, a stratified sample on the basis of sex and age are from the different schools of Ajmer city. (India). Their mean ages were grade 6, 10 years 9 months grade 7, 11 years 6 months; grade 8; 13 years 1 month; grade 9, 14 years 1 month; grade 10, 15 years 6 months; grade 11, 17 years 2 months.

Procedure

The conservation of mass, weight and volume tasks using plasticine and a conservation of volume task using metal cylinders were selected for the present study.

In the test for the conservation of mass, weight and volume tasks, two plasticine balls identical in size, shape and weight were taken. The tasks were administered to each student individually and scored and interpreted as suggested by Elking, 1961; 1962; Lawson and Renner, 1974.

While administering these three tasks, the teacher asked the following questions :

(i) Teacher, "Do both balls have the same amount of plasticine, is there as much plasticine in this ball as in this one ?" Student was encouraged to "make them the same," if he doubted the equality of the balls (Identify equation).

(ii) Suppose I roll one of the balls out in to a sausage, will there be as much plasticine in the sausage as in the ball, will they both have the same amount of clay ? (prediction question).

(iii) After students prediction, teacher actually made one of the balls into a sausage while students looked on. Teacher, "Is there as much plasticine in the ball as in the sausage, do they both have the same amount of clay ?" (Judgement question)

(iv) Teacher, "why is that?" Give explanation for your answer (Explanation question).

Exactly same procedure was used to test for the conservation of weight and volume, the only difference was that in each question in place of the 'amount' the word 'weight' and 'volume' was substituted. Finally as a check, the following question was set.

(v) The teacher showed the two identical glasses filled equally high with water and asked, "suppose I place the sausage in one glass and the ball in another, whether the rise of water would be equal or unequal in it, explain your answer."

The conservation of volume using metal cylinders task was administered, scored and interpreted as suggested by Lawson and Renner, 1974. Lawson, Blake and Nordland, 1974: Renner, 1977. The teacher showed the students two equal measuring jars partially filled with water and two cylinders of the same size but of different weights, that asked the following questions :

(i) Are the two cylinders of equal volume ? (Identity question)

(ii) Suppose I dip the cylinders in the water, "will the rise in the level of water be the same by both the cylinders ?" (Prediction question)

(iii) The teacher, then immersed the beavier cylinder into one of the measuring jar of water. The teacher, "Will the water in the second measuring jar rise equally to the water in the first measuring jar when the lighter cylinder is immersed in the measuring jar ?" (Judgement question).

(iv) Teacher, "why is that, give explanation for your answer ?" (Explanation question).

The conservation tasks were first administered for pilot testing in other schools and it was observed that most of the students upto IX class performed correctly on conservation of mass and weight tasks and all the students of X and XI classes answered correctly these tasks. While this was not the case with the conservation of volume tasks using the plasticine and metal cylinders, i. e. most of the students could not attempt it correctly. Finally it was decided to administer all the four conservation of mass, weight, volume tasks to class VI to IX students and only the two conservation of volume tasks to the class X and XI students. The results were analysed to investigate the fine structure and schema interaction for specific Piagetian tasks and prediction for hierarchical attainment of concepts.

Result

The performance of the students of class VI to XI on various Piagetian tasks are sumarised in the table I and II. The results shown in table I indicate that almost all all the students are able to perform correctly on conservation of mass and conservation of weight tasks upto IX class. The ability increases from class VI to IX class, while there is no significant difference between the performance on conservation of mass and weight tasks within the same class. The performance on the conservation of volume using plasticine is very poor. Only 10%, 25% and 28% of the students could perform correctly in IX, X and XI class

TABLE—I

Showing Number and Percentage of the Class VI to IX Students Attempted Correctly the Different Type of uesQtions of Piagetian Tasks

Piagetian tasks and the different types of question	Performance of the Students							
	Number of students attempted the questions correctly				Percentage of the Students attmpted the question correctly			
	VI	VII	VIII	IX	VI	VII	VIII	IX
1. Conservation of Mass								
(a) Prediction	17	26	24	30	57%	87%	80%	100%
(b) Judgement	15	25	23	30	50%	84%	77%	100%
(c) Explanation	11	22	22	29	37%	74%	74%	97%
2. Conservation of Weight								
(a) Prediction	17	23	29	30	57%	77%	97%	100%
(b) Judgement	11	23	29	30	37%	77%	97%	100%
(c) Explanation	10	20	23	28	34%	67%	77%	94%
3. Conservation of Volume using Plasticine								
(a) Prediction	5	5	4	7	17%	17%	14%	24%
(b) Judgement	3	5	3	7	10%	17%	10%	24%
(c) Explanation	1	3	2	6	4%	10%	7%	20%
(d) Water displacement	1	1	2	3	4%	4%	7%	10%
4. Conservation of Volume using Metal Cylinders								
(a) Prediction	7	8	14	21	24%	27%	47%	70%
(b) Judgement	6	7	10	20	20%	24%	34%	67%
(c) Explanation	5	5	8	17	17%	17%	27%	57%

TABLE—II

Showing the Number and Percentage of Class X & XI Students Attempted Correctly the Different Types of Questions of Piagetian Tasks

Piagetian tasks and different types of questions	Performance of the Students			
	Number of Students attempted the questions correctly		Percentage of Students attempted the questions correctly	
	X	XI	X	XI
1. Conservation of Volume using Plasticine				
(a) Prediction	36	64	36%	36%
(b) Judgement	32	62	32%	35%
(c) Explanation	30	60	30%	34%
(d) Water displacement	25	51	25%	28%
2. Conservation of Volume using Metal Cylinders				
(a) Prediction	76	145	76%	80%
(b) Judgement	70	134	70%	75%
(c) Explanation	68	131	68%	73%

respectively. Most of the students were even unable to predict that the volume of the sausage and the ball is the same. The performance on the conservation of volume using metal cylinder is comparatively better. About 17%, 17%, 27%, 57%, 68% and 73% of the students performed correctly on the task from classes VI, VII, VIII, IX, X, XI respectively. Though both the tasks measure the volume conservation reasoning ability but the result shows that most of the students (72%) even upto XI class are unable to attempt correctly the conservation of volume using plasticine task while a few students (27%) in XI class were unable to perform correctly the metal cylinder task.

Discussion

The results for the conservation of mass and conservation of weight tasks are in agreement with the studies reported by Piaget (Inhelder & Piaget, 1958); Elkind (1961, 1962); Brainered (1970); Lawson & Renner, (1974). Piaget used the conservation of volume task using liquid (Inhelder & Piaget, 1958) and indicated that the children develop the the conservation of volume concept at about 11-12 years of age. Elkind (1962) found that only 58% of the college students selected for the study could attempt the plasticine task correctly and only 47% senior school students (Elkind 1961) could attempt it correctly. Similar findings were reported by Towler and Wheatley (1971), which are quite in agreement with the findings reported in the present study. The results clearly indicate that the conservation ability is acquired in a seqence and is in agreement with the various studies reported elsewhere.

For metal cylinder task, the general performance of the the students in all the classes is far better as compared to plasticine task, though both the task mainly measure the

the volume conservation ability. This significant difference in performance on the two volume conservation tasks justifies the need for investigating the content structure for each specific task and to find out the various sub-concepts necessary for correct performance on the task. The sub-concepts necessary for plasticine tasks are : (i) when a body (or plasticine) is changed in the form or shape (i. e. it is made longer or thinner or thicker or wider etc.), then also its volume remains conserved and (ii) the volume of the water displaced is same as the volume of the body immersed in it. The Sub-concepts necessary for the metal cylinder tasks are : (i) the volume of the water displaced is same as the volume of the body immersed in it, and (ii) the volume of the water displaced is independent of mass of the body immersed in it.

The above content structures of the tasks and the results obtained in the present study indicate that most of the children at XI class have developed the concept that the volume of the water displaced is same as the volume of the body immersedin it and is independent of the mass of body. While very few XI class students could acquire the concept that when a body (plasticine) is changed in the form or shape then also its volume remains constant. It shows that there are a variety of variables related to task difficulty : the logical structure, familiarity with the materials and various sub-concepts necessary for the solution of the task. Similar findings were reported by Lawson, Nordland and Devito, 1975; Lawson and Blake, 1974; Blake, Lawson and Nordland, 1976 In the light of this research study, it seems reasonable to conclude that we should not rely upon the use of any single task to make an adequate characterization of the cognitive level of the students but the task difficulty should also be taken into consideration.

Study No. 13

Child's Conception of Movement : an Empirical Study

The theory of cognitive development as enunciated by J. Piaget and his Methode Clinique are increasingly attracting the attention of the researchers, both, in India and abroad. Now it is being accepted though 'slowly and grudgingly'. When applied to education, his ideas are resulting in efforts to develop new models of teaching. Studies replicated in different countries representing varying cultural pattern (Dasen, 1976) though support, in general, the stage based theory, bring to light the possible time lag of 3-5 years from that suggested by Piaget in the acquistion of stages Further, the findings of different authors including Gross (1972), William (1975), Al-Sheikh (1974), Hobbs (1973), Graves, 1972), Siegel (1971), Tisher (1971), Towler and Wheatley (1971), Modgil and Modgil, Vol. 1-8 (1976), as regard the difference in the development of the boys and girls are not mutually supporting in totality. S.D' Souza et al. (1968) analysed that the social differences and sex differences were associated with quality and quantity of education on the Chandigarh population. Possibility of Hump effect as suggested by N. Vaidya et al. (1976) adds another element to the studies on the process of cognitive development.

Movement being one of the basic concepts of Science and Mathematics education was thought out to be studied with the chandigarh population on the lines suggested by Piaget (1970).

Objectives of the Study

The following objectives guided the present study :

1. To study the sequence of development of different stages as determined by the questions asked.
2. To compare the pattern of empircal and Piagetian order of responses.
3. To study the distribution of the acquisition of the concept of Movement at different age levels.
4. To compare the rate of development of the concept of Movement at different age levels.
5. To study the effect of intelligence on the development of the concept.
6. To compare the development of the concept in boys and girls.
7. To study the effect of social class on the development of the concept in the boys and girls.
8. To study the pattern of the child in the 'performance' situation.
9. To bring out the educational implication of the development of the concept.

Hypothesis

The study was taken up to test the following hypotheses :

1. The development of the concept of Movement in Children is a function of age.
2. The development of the concept of Movement in children depends upon their level of intelligence.
3. The social class of the family effects the development of the concept of Movement.
4. Sex differences exist in relation to concept of Movement.

Design of the study

The data were collected on a sample of 240 boys and 240 girls spread over equally (20 boys and 20 girls) in all the twelve age groups of one year interval between the age range of 4^+ through 15^+. The sample belonged to the school going population of fifteen schools in chandigarh and its suburb and was from the middle upper strata of the lower and the lower strata, of the higher social class groups.

The concept of movement was studied through five Piagetian tasks : Alternative Directions of Travel (Task I), Order of Succession Inherent in Cyclic Movements (Task II). The path Traversed (Task III), The Composition of Displacements (Task IV) and the Relative Movements (Task V).

For this purpose locally devised apparatus for the Piagetian Tasks I to V, Raven's Progressive Matrices and social class scale were used. Age of the child was calculated from the school records.

Different tools were administered to each of the subjects individually in the interview–cum-experimental setting. The responses at the 'performance level' were scored as right or wrong. A right response was given a score of one. The total of correct responses on a Task was taken as the score of individual on that task. Sum of scores of all the five Tasks was taken as the score on the Concept of Movement.

The results of the study were the outcomes of statistical analysis employing proportions, percentages, mean score, t-ratio, Pearson's product moment correlation, Scaleogram analysis and two way analysis of Variance.

The developmental sequences of the concepts implicit in all the five Piagetian tasks separately was determined on the basis of difficulty order of the questions as indicated by the total of proportion of subjects answering different questions correctly.

The different hypotheses advanced in this study were first tested Task-wise and then for the concept of movement.

Conclusions

Some major conclusions of the study are summarised below:

1. More than seventy five percent of the inter-age group differences in the mean task scores of the different tasks were statistically significant indicating the increasing development of the related concepts with age.

2. The sub-concepts involving conceptual estimation and composition of displacements without measurements were conserved later than those with their estimation and composition after measurements. As such was the order of developments of the sub-concepts in relation to the task. The Path Traversed was not the same in this 'performance' level study as in the Piagetian "competency" level study. These results were further confirmed by the results of experiment with Tasks : The Composition of Displacement and; The Relative Movements.

3. Some of the children exhibited different order of difficulty of the questions than that exhibited by the majority of the children at that age level. This variation did not decrease with age.

4. The proportion of children who appeared to be consistently operational on all the five tasks were 7.5, 5.0, 2.5, 2.5 and 2.5 at the age levels 15^+, 14^+, 13^+, 12^+, and 11^+ respectively.

5. The proportion of children at the age of 15^+ who were considered as operational on all the five tasks separately were : 0.875 (Task I); 1.0 (Task II); 0.90 (Task III); 0.3 (Task IV) and 0.125 (Task V).

6. The sample at an age level distributed itself at different stages of development. The sample was of maximum heterogeneity at age levels 5^+, 6^+, $8,^+$, 10^+ and 12^+ on the tasks I, II, III, IV and V respectively. The number of developmental stages into which the sample distributed itself decreased with age on either side of the age of maximum heterogeneity. This was observed on all the five tasks and the cumulative picture of all the five tasks.

7. More than 50% of the sample at the age level 10^+ and above behaved as conservers on the Tasks I, II and III. The corresponding age level for the composition of displacement (Task IV) was 11^+, where as only 15% of the sample could reflect the conservation of the Relative Movements (Task V) at 11^+.

8. The hypothetico deductive level of reasoning was demonstrated by 25% at the age of $12^+$and by 12% at the age of 13^+ on the composition of displacements and relative movements respectively.

9. Transformation from transitional to concrete operations took 3 to 4 years depending upon the nature of the task. The transformation from concrete operations to the formal operations was considered to be more a function of experience than of physical maturity.

10. Rote of task development was not found to be the same at different age levels on any of the five Tasks.

11. The concept development curves can be divided into three parts : initially lower rate of development upto the age of 5 years, than the higher rate of development upto the age of 10-11 years and then, again, the lower rate of development due to ceiling effect.

12. Significant inter age group differences in the top 25% and bottom 25% subgroups (by age) at the age levels 5^+, 7^+ and 10^+ indicated that rate of development of the concept of movement is faster here than at the other age levels.

13. The higher intelligence sub-group at different age levels was found to indicate the higher level of task acquisition. The sub-group was also found to attain operativety earlier than by the lower intellilgence subgroup.

14. Flcutations in the task development curves were indicated by the top 25% (TIG) and bottom 25% (BIG) sub-groups by intelligence. So, the development of the concept was not considered to be smooth either with the TIG or with BIG.

15. The TIG. experienced 'humps' at a lower physical maturity level than those by the BIG. These humps were found to be approximately at the same conceptual development level in both the sub-groups.

16. Generally, at an age level the higher intelligence sub-Group was found to be at the higher stages of concept development than the lower intelligence sub-group.

17. The boys exhibited, generally, higher level of development of the different tasks at all the age levels than

the girls. These differences were statistically significant at the age level 9^+ and 14^+ only and were in favour of the boys.

18. The higher social class sub-group (as determined by the educational level of the parents, professional level of the parents and the total income of the family) was found to indifcate significantly higher conceptual development level than the lower social class sub-group at the age levels 8^+ and 9^+ only.

19. At the other age levels, there is a possibility that, the difference in the social status of the two sub-groups might not be sufficiennt enough to cause significant differences in the concept development of the school going sample.

20. There was indicated a time lag in the responses at performance level determined empirically in the present study when compared with those at competency level as determined by Piaget, both at the concerete and formal operational stages.

The study made to think of the possiblity of situational distractors, tendency of response satisfaction, lack of class room practices related to the permissive and corrective environment as some of the factors effecting concept attainment. It emphasized the necessity of organised experiences to accelerate the rate of acquisition of formal operations and more practice in the use of scale and estimation of length for the earlier acquisition of the related concepts.

Chapter V

Varied Thumb-nail Studies and Findings

Introduction

The investigation of human thought is a phenomenon of recent origin which has been investigated from the several vantage points. The Geneva school has recently contributed a lot here using the 'Method of Critical Exploration', which, in turn, has generated a lot of interest in this neglected area all over the world. In the documentation which follows, are included two sets of studies, namely, general and specific to the area of school science education. Attempt is than made at the end to draw some conclusions of general interest if they at all could be drawn. The main difficulty here is the highly varied aims and objectives of the various studies, their modes of sampling and specific tools and techniques suiting individual requirements. So a pattern of findings is hinted at which could remain for some time a matter of experimentation and reflection. Always open to scrutiny, it does inform about the type of road to be traversed for answering the basic questions.

Table of Studies

S. No.	Author (s)	Year	Title of the Study	Main Finding (s)
1	2	3	4	5
1.	Heidbreder, E.	1928	Problem Solving in Children and Adults.	Reactions and sensitivity to problems increased from subjective attitude, to a more objective attitude. Whereas the general pattern of the solution became more explicit and definite, new rigidity set in with increasing age.
2.	Russell, R. W. and Dennis, W.	1939	Studies in Animism I:A Standardized Procedure for the Investigation of Animism.	All stages were present at all ages included in the investigation.
3.	Bailey, R. G.	1941	The Difficulty Level of Certain Science Concepts.	High mental ability favoured concept development and added allied work as well as activities on the given unit of science.

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4.	Kyle, T.	1950	An Investigation of the Thought Processes of a Group of 14-year olds During the Solving of a Scientific Problem.	(i) Able pupils do not solve problem in stages. In fact, they jump from stage to stage. (ii) A problem becomes real for a person only when he has some rudimentary foresight of tentative solution. (iii) A 'doing group' went further towards a solution than a 'thinking group'.
5.	Cohen J and Hensel, C.	1955	The Idea of Independence	Most of the mid adolescent pupils (under 75 percent) fail to develop the concept of independence.
6.	Buswell	1956	Patterns of Thinking in Solving Problems	(i) The subjects experience difficulty in expressing concepts verbally which they had in fact acquired. (ii) They do not estimate the answers before they start solving problems.

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				(iii) Their failure to distinguish between the relevant and irrelevant aspects of the problem attracts all sorts responses. Variety rather than similarity in the sequence of thinking was the most striking and outstanding characteristics even when common and uniform patterns of thinking were seen during the entire act of problem solving.
7.	Inhelder B and Piaget, J.	1958	The Growth of Logical Thinking : From Childhood to Adolescence.	(i) Concrete operational subjects can describe the results of their experiments but fail to hold other factors constant. (ii) Formal operational subjects attempt to prove something through control experiments.

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				(iii) Considering experimentation elsewhere, the hypothesized setting and testing behaviour does not become highly rampant.
8.	Wheeler	1958	Studies In The Development of Reasoning In School Children.	Contradicts Piaget. Elementary schemata are very much there even among young children. It is their subsequent development which describes the difference in performance between the young.
9.	Peel, E. A.	1960	The Pupil's Thinking	Confirms Piaget in principle. Identifies four kinds of thinking, namely, thematic, explanatory, productive and integrative.
10.	Lovell, K.	1961	A Follow-up Study of Inhelder and Piaget's 'The Growth of Logical Thinking'.	Confirms Piaget in principle. The pupil's of low academic ability fail to develop formal operations even past their mid-adolescence.

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11.	Mealings	1961	Some Aspects of Problem Solving in Science.	(i) Problem solving in science is more related to intelligence than to chronological age. (ii) There appears to be a minimum mental age of 13 years before a child can reason formally about a problem. (iii) Children should not be expected to solve abstract problems below the mental age of 16 plus. (iv) There is a time lag between the empirical solution and formal solution.
12.	Smoke (Ed. Harris & Schelwaln)	1961	Selected Readings on Learning Process.	(i) There is some form of grouping in concept formation. (ii) In firm concept formation only, hypotheses are set up and tested for their validity.

1	2	3	4	5
				(iii) Insightful behaviour is present in some situations. (iv) Subjects have difficulty in expressing their concepts verbally which infact they had acquired.
13.	Beard, R. M.	1962	Children's Reasoning	There are vast individual differences in levels of thinking among adolescent pupils studying in different schools. Previous classroom experiences appeared to play an important factor in the separation of variables.
14.	Bruner, J. S. Goodnow, J.J. and Aust in G.A.	1962	A Study of Thinking	Four distinct strategies were distinguished, by which a person may from the given concept : simultaneous scanning; successive scanning; conservative focusing; focus gambling.
15.	Case, R.D. and Collinson J.M.	1962	The Development of Formal Thinking in	Scores on formal thought varied even when the children were matched on CA and

1	2	3	4	5
			Comprehensi[illegible]	MA but were drawn from different cultural background.
16.	Elkind, D.	1962	Quantity Conceptions in College Students	(i) Most of the college students were still at the concrete operational level. (ii) Only 58 percent of them were clear about conservation of volume concept.
17.	Sleisnick, I. L.	1962	The Effectiveness of a Unified Science in the High School Curriculum.	Focus on key concepts definitely influences learning.
18.	Vaidya, N.	1964	A Study of Problem Solving in Science Among Certain Groups of Adolescent Children	(i) Though adolescent pupils are in a position to state hypot[illegible]s most of them are not in a positio[illegible] test them. (ii) They do not, contrary to Piaget, exhaust all possibilities.

1	2	3	4	5
				(iii) A given problem is solved over a wide I.Q. range not only within a given age group but also across the various age groups.
19.	Jackson, S.	1965	The Growth of Logical Thinking in Normal and Sub-Normal Children	About half of the 15-year-olds do attain the formal operational stage.
20.	Stone, D.R.	1965	Developmental Aspects of Hierarchal Concept Attainment. (Final Report).	(i) Scores did not increase with age. (ii) Sex difference were not noticed.
21.	Lovell, K and Butterworth, J.B.	1966	Abilities Underlying the Understanding of Proportionality.	Majority of the adolescent pupils do not reach the formal operational stage.

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22.	Yudin, L.W.	1966	Formal Thought in Adolescence as a Function of Intelligence	Even adolescent pupils of average intelligence, contrary to Piaget, show concrete thinking behaviour as defined by Piaget. Added age is an important factor in the development of formal thought.
23.	Gunnels, F.G.	1967	A Study of the Development in Logical Judgments in Science of Successful and Unsuccessful Problem Solvers in Grades Four Through Nine.	(i) Age is an important factor in the development of formal thought. (ii) Stage concept in thought develops sequentially is confirmed.
24	FJellman, J.S.	1969	Methods of Investigating Cognitive Development of Children in Rural Kenya (Some Kamba Results)	Thought becomes more and more complex with age. Their practical ability to sort out far exceeds their ability to verbalize even with very familiar animals.

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25.	Dale, L G.	1970	The Growth of Systematic Thinking : Replication and Analysis of Piaget's First Chemical Experiment.	Very few adolescents perform at the formal operational level.
26.	Karplus R and Karplus, E.F.	1970	Intellectual Development Beyond Elementary School I : Deductive logic.	Only 40 per cent of the group of physics teachers used formal operations to solve the Island problem.
27.	Bart, W.M.	1971	The Factor Structure of Formal Operations	In addition to the large general factor, the formal thought did comprise verbal as well as non verbal thought.
28.	Higgins-Trenk, A and Gaite A.J.	1971	Elusiveness of Formal Operational Thought	The American adolescent pupils attain formal thought only at the age of nineteen or so.

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29.	Lee. L.C.	1971	The Concomitant Development of Cognitive and Moral Modes of Thought : A Test of Selected Deductions of Piaget's Theory.	About half of the subjects fail to attain formal thought.
30.	Kohlberg and Gilligan, C.	1971	The Adolescent as a Philosopher-The Discovery of the Self in a Post Conventional World	All normal children attain the concrete operational level but very few the formal operational level.
31.	Mckinnon, J. W. and Renner, J. W.	1971	Are Colleges Concerned with Intellectual Development ?	About three fourths of college freshmen fail to attain formal stage.
32.	Mecke, G and Mecke, V.	1971	The Development of Formal Thought as	All the fifteen years old adolescent pupils manifested formal thought who systematically

1	2	3	4	5
			Shown by Explanations of the Oscillations of a Pendulum : A Replication Study	approached the simple pendulum problem.
33.	Dulit	1972	Adolescent Thinking a la Piaget : The Formal Stage	Even two fifths of the gifted pupils (16-17 years) fail to attain formal thought as tested though several Piaget type problems. Even among the general population (20-55 years) about two thirds fail to achieve formal thought.
34.	Hale, J.P.	1972	An Investigation of Two Formal Operational Schemata in Adolescents Enrolled in the ISCS Class Rooms of Three Selected Teachers.	A large number of the sample were at the concrete and transitional stage. Students whose scores were low in reading comprehension were not necessarily poor thinkers and those with high scores in reading comprehension were not necessarily good thinkers.

1	2	3	4	5
				Most of the adolescent pupils fail to attain formal thought. Scores on reading and thinking do not go together.
35.	Lang, W.A.F.	1972	Difficulty of Some Concepts in Physics.	Even eleventh graders fail to manifest formal thinking on problems dealing with mass, weight, properties, speed, velocity and acceleration.
36.	Lengel, R A. and Buell, R.R.	1972	Exclusion of Irrelevent Factors (The Pendulum Problem)	(i) Between grades 7 to 12, there is gradual growth in the logical operations of exclusion. (ii) No sex differences were noticed. (iii) Measures of I. Q. and socio-economic status had little relation to conservation.
37.	Lewis, W.R.	1972	The Influence of Age, Sex and School Size Upon the Development of Formal Operational Thought.	Formal thinking is highly dependent on age rather than any other variable.

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38.	Lunzer, E.A. Harrison, C and Davey, M.	1972	The Four Card Problem and the Generality of Formal Reasoning.	Where as familiarity with the problem influences performance, the incidence of formal operations is quite low in the general population.
39.	Renner, J.W. and Stafford, D.G.	1972	Teaching Science in the Secondary School	If formal operations begin at 11$^+$ as hypothesized by Piaget, about one seventh pupils between (10-12 years) appear to posses it.
40.	Wason and Johnson Laird	1972	Psychology of Reasoning : Structure and Content.	Very few adults i. e., only the very intelligent among them could solve the four card problem successfully.
41.	Wells, J.	1972	Some Aspects of Adolescent Thinking in Science	Mental age rather than chronological age determines the quality of the thinking. However, a wide spread of mean was noticed both for C. A. and M. A. when thinking was classified in various ways : Describer level, Extended describer level, Explainer, Using analogy and Using inference etc ,

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42.	Weybright, LD	1972	Developmental and Methodological Issues in the Growth of Logical Thinking in Adolescence.	The Piagetian tasks attracts wider thinking than imagined by Piaget and Inhelder which attempts to fill in the gaps left by them when transition of thought between the concrete and the formal stages is considered.
43.	Ghatala, E.S.	1973	The Cognitive Operations Specified in the Model	In conceptual learning and development, there are four levels of mastery. The internal conditions of concept learning comprise the level of operation as well as the acquisition of the concept preceding this level.
44.	Griffiths, DH	1973	The Study of the Cognitive Development of Science Students in Introductory Level Courses.	Contrary to Piaget, sufficiently less than half attain formal thought which definitely hinders their performance on the experimental equipment despite the fact they had at their disposal the specialized vocabulary.

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45.	Misra, R.M.	1973	Role of Hypotheses in Problem Solving Among Grade X Science Students.	(i) There is no significant difference between top group and bottom group on the number of hypotheses emitted by them. (ii) A given problem is solved over a wide I. Q. range i. e. a low I Q. pupil may solve the problem successfully where as high I. Q. pupil may fail to do so. (iii) Many adolescent pupils experience difficulty in testing hypotheses.
46.	Osicki, K.J.	1973	Affective and Cognitive Development : Comparison of Need Achievement and Risk Level with Piagetian Levels of Cognitive	Cognitive development does not vary with either need-achievement or risk level.

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			Development for Two Socio-Economic Groups.	
47.	Ross, R.J.	1973	Some Empirical Parameters of Formal Thinking.	About half of the undergraduates fail to reach the formal level.
48.	Saarni, CI	1973	Piagetian Operations and Field Independence as Factors in Children's Problem Solving Performance.	Whereas the field independence did not clarify individual differences meaningfully, the Piagetian developmental level did predict the problem solving performance reasonably well.
49.	Ward, R.W.	1973	A Study of the Development in Fourth, Fifth and Sixth Grade Children of an Under-	The particulate model of matter is not understood by the tenth graders. Secondly, the ethnic background, sex and type of school like variables did not show any signi-

1	2	3	4	5
			standing of a Particulate Model of Matter.	ficant relationships with performance.
50.	Weeks, R.T.	1973	The Relationship of Grade, Sex, Socio-Economic Status, Scholastic Aptitude and School Achievement to Formal Operations Attainment in a Group of Junior High School Students.	Ninth graders fail to show formal thinking.
51.	Weitz, L.J. Bynum, T.W. Thomas J.A. & Steger J.A.	1973	Piaget's System of 16 Binary Operations : an Empirical Investigation	Within the age group (9-16 years) only about one third of the sixteen operations were used which even failed to show developmental trends.

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52.	Blasi, A. & Hoeffel, E.C.	197	Adolescence and Formal Operations.	The logical foundation for conceptual thought disappears when meanings vary on possibility and reflectivity on analysis.
53.	Case, R.	1974	Learning and Intellectual Development	Even the 7-8 years intelligent and field independent pupils were able to acquire the control of variables in the absence of conservations of weight or combinatorial grouping.
54.	Docherty E.M.	1974	Identifying Concrete and Formal Operational Children	With the help of the Piagetian tasks, it is possible to identify the concrete and the formal stage through cluster analysis
55.	Graybill, L.A.	1974	A Study of Sex Differences in the Transition from Concrete to Formal Thinking Patterns	Sex differences for varying boys in logical thinking were noticed.

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56.	Howe, A.	1974	Formal Operationl Thought and the High School Science Curriculum.	Barring a few of high mental ability, the rest of the secondary students of higher grades failed to reach the formal operational thought.
57.	Karplus et al	1874	Intellectual Development Beyond Elementary School IV. Ratio : The Influence of Cognitive Style.	About four fifths of the high school students fail to attain the scheme of proportions.
58.	Kidder, F.R.	1974	Investigation of Nine, Eleven and Thirteen Year Old Children's Comprehension of Elucidean Transformations.	Failure to conserve length attracted errors on problems involving Euclidean Transformations.
59.	Lawson, A.E.	1974	Relationship of Concrete and Formal	The percentages of students studying chemistry, physics and biology manifesting formal

1	2	3	4	5
			Operational Science Subject matter and the Development Level of the Learner.	thought are 64, 63 and 35.
60.	Lawson and Renner	1974	A Quantitative Analysis of Responses to Piagetian Tasks and Its Implications for Curriculum.	About 22 percent of the college freshmen operate at formal-operational level while 51% and 27% are found at the concrete operational and post-concrete operational level respectively.
61.	Nordland et al	1974	A Study of Levels of Concrete Ability in Disadvantaged Junior and Senior High School Science Students.	Only about one seventh of the high school students show formal thinking.
62.	Somerville S.C.	1974	The Pendulum Problem: Patterns of Performance	The development of formal thought is strongly dependent on age rather than sex

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			Defining Developmental Stages.	and even the type of school.
63.	Wonzy, C.D.	1974	The Effects of Culture and Education on The Acquistion of Formal Operational Thinking.	Formal Thinking (or operations) is seen to be promoted by the sub-urban cultural background
64.	Abramowitz, S.	1975	Adolescent Understanding of Proportionality Skills Necessary for its Understanding.	The nature or the content of the problems definitely mars the performance of the transitional thinkers between the concrete and the formal stage on the schemes of proportionality.
65.	Arlin, P.K.	1975	Cognitive Development in Adulthood: a Fifth Stage ?	About three fifths of the formal thinkers fail to be problem finders.
66.	Bantista, L B.	1975	The Relationship Between Intellectual	The concrete operational students did not differ significantly from the formal operational

1	2	3	4	5
			Levels and Achievement in the Comprehension of Concepts Classified According to Scheme Dervied from Piagetian Model	students involving concrete thought only. It is an expected finding.
67.	Bates, G.C.	1975	More on the Problem of Physics Enrolment.	The incidence of formal reasoning increases from biology through chemistry to physics.
68.	Chiapetta E.L. and Collette, A.T.	1975	The Effectiveness of Verbal Label Training in Aiding Second Grade Pupils to Transfer Their Classificatory Skills.	Majority of the late adolescents and adults in U.S.A. function at the concrete stage of mental development.
69.	Dettrick, G.W.	1975	A Study of the Structure of Piagetian Logical and Infra-Logical	Contrary to Piaget, formal reasoning does not develop at all at 11. It is usually delayed by about 2 to 3 years when the

1	2	3	4	5
			Grouping Within the Concrete Operational Period.	cognitive processes really become functional.
70.	Ennis	1975	Children's Ability to Handle Piaget's Proportional Logic : Conceptional Critique.	Some of the complex operations, contrary to Piaget, are used correctly by the 7–8 years old children. There is also apparently no connection between isolating variables and combinatorial grouping.
71.	Graybill, L.A.	1975	Sex Differences in Problem Solving Ability.	Sex differences favouring boys in formal thinking were noticed.
72.	Hathway, W.E.	1975	The Unique Contribution of Piagetian Measurement to Diagnosis, Prognosis and	Piagetian factors do dominantly associate themselves with the various measures of school achievement.

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			Research of Children's Mental Development.	
73.	Jurascheck, W.A	1975	The Performance of Prospective Teachers on Certain Piagetian Tasks.	About half of the elementary school teachers fail to attain formal thought.
74.	Karplus, Karplus, Formisano and Paulsen	1975	A Proprtional Reasoning and Control of Variables in Seven Countries.	About three fourths of the pupils definitely fail to develop formal thought on problems relating to proportion and control of variables in seven different countries. The scores on the two problems were not found related to each other over the entire population.
75.	Keating, D.P.	1975	Prococious Cognitive Development at the Level of Formal Operations	Majority of the adolescent pupils do not show formal thinking.

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76.	Lawson, A.E. and Renner, J.W.	1975	Relationship of Science Subject Matter and Developmental Levels of Learners	About two thirds of the adolescent pupils do not operate at the formal level while acquiring abstract scientific concepts.
77.	Rajput, M.D.	1975	A Study of the Scheme of Proportion Among Certain Groups of Adolescent pupils	i. No significant sex differences were noticed on the scheme of proportion. ii. Fluctuations in performance were noticed from lower grades to the higher grades of course with dominating increasing trend with age.
78.	Raven, R.J and Gurerin. R	1975	Quasi-simplex Analysis of Piaget's Operative Structure and Stages.	The sequential development supported.

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79.	Sayre and Ball	1975	Piagetian Cognitive Development and Achievement in Science	There is a gradual growth of formal thought among science students to complete the Piagetian tasks.
80.	Sayre, S and Daniel, W.B.	1975	Piagetian Cognitive Development and Achievement in Science	There is gradual growth of formal thought during adolescence.
81.	Schwebel, M.	1975	Formal Operations in College Freshmen	About four fifths of them do not show formal thinking on the three Piagetian tasks.
82.	Valentine, E.R.	1975	Performance on Two Reasoning Tests in Relation to Intelligence, Divergence and Interference Proneness	High Convergent thinking does not guarantee success on reasoning tests.
83.	Waite, J.B.	1975	A Study Comparing College Science Students, Performance on	There is no direct bearing of varied cultural backgrounds on the performance of Piaget type tasks.

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			Piagetian Type Tasks, Including Cross Cultural Comparisons.	
84.	Wonzy C.D. and Cox D.C.	1975	The Effects of Task Differences on the Assesment of Formal Operational Thinking.	Age definitely interacted with the number of variables. A problem becomes more difficult for the adolescent pupils to solve if more variables are injected into it
85.	Vaidya, N	1975	The Growth of Logical Thinking in Science During Adolescence.	i. The complex thinking processes arise from simple thinking processes. ii. Expcept occassional fluctutations, the mean performance on the various schemes of thought shows an increasing trend with grade. iii. In case these fluctuations are taken seriously, hump effect is suspected.

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				(iv) Where as the adolescent pupils are in a position to set up hypotheses, they are not in a position to test them contrary to Piaget's view.
86.	Clayton V and Overton, W.F.	1976	Concrete and Formal Thought Processes in Young Adulthood and Old age.	There is variation in formal thought with age.
87.	Cloutiers R and Goldschmid, W.F.	1976	Individual Differences in the Development of Formal Reasoning	Significant correlations have been obtained between scores on the proportion test and non-verbal intellectual capacity as measured by the Raven's RPM.
88.	Dave, P.N.	1976	An Experimental Project in Physics for the Validation of An Adva-	i. Taking the whole data into consideration, knowledge, understanding and application do constitute a heirarchy.

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			nced Curriculum Model of Cognitive Learning, Heirarchy in Cognitive Learning.	ii. More consistency in the performance of the experimental group is noticed iii. Recognition and prediction remained at the bottom and the top of the hierarchical structure respectively.
89.	Germain, J.G. et al	1976	The Personality of the Child and the Utilization of Operative Thought	Significant relationships appeared between the different measures of operational thinking and different personality variables.
90.	Griffiths. D.H.	1976	Physics Teaching Does it Hinder Intellectual Development ?	Formal thinking is necessary to the development of abstract concepts in physics.
91.	Karplus, R and	1976	Implication of Accumulating Data on	About two thirds of the general population between 13+ to 45+ hardly show formal

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	Arons, A.B.		Levels, of Intellectual Development.	thought.
92.	Khun, D.	1976	Relation of Two Piagetian Stage Transition and I.Q.	The correlation coefficient between mental age and the Piagetian tasks become less and less marked as it tends to become fully formal.
93.	Lawson, A.E. and Blake, A.J.D.	1976	Concrete and Formal Thinking Abilites in High School Biology Students as Measured by Three Separate Instruments.	About fifty percent of the high school biology students do not show formal thought.
94.	Linn and Levine	1976	Adolescent Reasoning: The Development of the Ability to Control Variables.	i. When the results were stressed and the procedure was hidden from view, the performance of the young adolescent pupils was impaired then the older ones.

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				The gap between the two being as wide as four years. ii. Both groups of subjects performed similarly on the problems when the results were not shown.
95.	Okeke, E.A.C.	1976	A Study of the Understanding in Nigerian School Certificate Biology Candidates of the Concepts of Reproduction, Transpost Mechanisms and Growth.	About 75 p. c. of the candidates failed to show formal thinking on every task. No sex differences exist when it comes to the understanding of the transport mechanisms.
96.	Copper, D.A. et al	1977	The Relation Between Formal Operations and a Possible Fifth Stage of Cognitive Development.	No relation existed between performance on problem finding and formal operations task.

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97.	Joyce, L.K.	1977	A Study of Formal Reasoning in Elementary Education Majors.	Subjects show better performance on problems involving syllogisms than on the Pendulum problem. Testing of hypotheses is little evident among two thirds of them.
98.	Mortorano, S.C.	1977	A Developmental Analysis of Performance on Piaget's Formal Operations Tasks.	Mean scores on the ten tasks increase with grade.
99.	Cantu, L.L. and Herren, J.D.	1978	Concrete and Formal Piagetian Stages and Science Concept Attainment.	Where as formal thinking is highly favourable to the development of concrete concepts, both the concrete and formal thinkers do benefit from pseudo examples.
100.	Grewal, A	1978	A Study of the Relationship Between Hypotheses Testing Abili-	There is significant relationship between hypotheses testing ability and the creativity variables like fluency and originality.

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			ty in Science and Creativity.	
101.	Linn M.C.	1978	Influence of Cognitive Style and Training on Tasks Requiring the Separation of Variables Schema	The manner of presentation influences performance which is however, effected by considering only a single measure of field dependence/independence factor.
102	Shayer, M and Wylam, H	1978	The Distribution of Piagetian Stages of Thinking in British Middle and Secondary School Children 14 to 16 years olds.	There appears to be a stay put in thinking i.e , beyond the age 15 years, there is no increase in the proportion of pupils showing formal thinking.
103.	Upadhyay, G.P.	1978	A Study of Intellectual Development and its Relationship with	Majority of the fifteen year olds do not operate at the formal level.

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			Intelligence and Achievement of X Grade Science Pupils.	
104.	Head. J.	1979	Personality and the Pursuit of Science	Supports Piaget in principle. Enhanced social interaction leads to decentring and hence, to added cognitive development.
105.	Kansakar, L	1979	A Study on the Exclusion of Variables During Adolescence.	i. The mean performance on all the problems shows an increasing trend in stating and testing of hypotheses with grade. ii. All the problems were strongly correlated with each other. iii. Using top 25 per cent and bottom 25 per cent groups, it was seen they differ significantly from each other in respect of age and grade but not in intelligence.

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106.	Pallrand, G.J.	1979	The Transition to Formal Thought	Higher age groups beyond adolescence manifest formal thinking abundantly.
107.	Walker, R.A. et al	1979	Written Piagetian Task Instrument: Its Development and Use	Concrete thinking dominates even at the age of 15 years i. e., little formal thinking is observed.
108.	Sandhu, T.S.	1980	A Factorial Study of Adolescent Thought Using Piaget Type Tasks	i. Performance on Piaget type tasks increases with age. ii. Boys perform either equal or better than girls on the tasks at respective age levels. iii. Significant correlation exists between intelligence and the adolescent thought and between academic achievement and adolescent thought. iv. Personality factors play a significant

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				role in development of adolescent thought.
109.	Jain, S.C.	1981	A Study of Problem Solving Behaviour in Physics Among Certain Groups of Adolescent Pupils	i. Problem solving ability differs significantly among pupils operating at three levels of intellectual development. ii. The performance on problems significanlty increased after hints were provided.
110.	Mathur, M	1981	A Study of Growth of Experimental Mind During Adolescence	I. Performance on Piaget type tasks shows an increasing trend with grade with quite a bit of fluctuations on certain tasks ii. The capacity to grasp the essence of the problem increases with grade
111.	Padmini, M.S.	1981	The Growth of Exclusion of Variables During Adolescence-A Study.	i. Adolescent pupils are in a position to state and test hypotheses in all grades. However, the mean performance

1	2	3	4	5
				increases with grade with occasional fluctuations. ii. Many adolescents are still found to operate at the concrete level. iii. The majority of the successful problem solvers are the fourteen year olds and the majority of the unsuccessful problem solvers are the ten year olds.
112.	Raizada, V.	1981	A Study of Relationship Between Problem Solving Ability and Some Relative Personality Traits Using Piagetian-Type Tasks.	i. Intelligence was found to be significantly correlated with all types of Piagetian tasks. ii. Except ‘ratio and proportion’. girls perform better than boys an all other types of Piagetian-tasks. ii. ‘Ergic tension’ was found to correlate significantly with most of the Piagetian tasks.

Concluding Statement

To study human mind in its entirety is to study the sources of knowledge, their nature, growth and development. So by implication, to 'study knowledge is to study man, for, knowledge enters intimately into all human life' (Margaret A. Boden), when it comes to the investigation of aim and objective, purpose, belief, morality, freedom, context, concept, structure and function etc., that is, all the varied sorts of mental phenomena. So one gets at the developing model of man as being built up by psychology. This being the ultimate objective, the above mentioned findings when consolidated, therefore, loosely hint at :

1. The human mind is highly dynamic. It naturally possesses quite a bit of spontaneous thought which needs to be explored for all practical purposes for human thinking.
2. Like Piaget, teachers should listen more and more to the inaccurate answers of their pupils and consequently improve their strategies and tactics of teaching based upon the knowledge, thus, gained.
3. Children stick to their thoughts firmly. When compelled to think, their erratic thought in several contexts appears to suffer hump before individual concepts finally settle down.
4. The concrete operational stage is quite dominant among normal adolescent pupils.
5. Where as the adolescent pupils are in a position to state hypotheses, they are not in a position to test them. The same is equally true of exhausting all the posibilities. At best, they can test one variable in most of the cases.
6. Content, context and instructional intention are some of the factors which influence learning. Also pupils

use words metamorphically. All this make access to child mind difficult.

7. Adolescent attack on problems is seen to increase with chronological age and grade. The stage concept is supported in principle.

8. It is possible to identify concrete and formal operational pupils through cluster analysis.

9. The different school subjects demand varying amounts of formal thought. In science, physics demands the most and biology, the least.

10. There appears to be significant relationship between scores on formal thought on one hand and achievement, creativity and only some personality factors on the other.

11. The very language of Piaget as well as of Piaget type tasks is deceptive. It is therefore, essential to establish equivalances among the various tasks empirically.

12. There is seen a sufficient time lag among the experimental solution, additional experimental solution and the formal solution.

13. Role of past experience as well as hints and cues is little understood in problem solving. The opinion is also more or less divided on sex differences in problem solving.

14. The psychometric and developmental studies on intelligence have yet to converge. There is still a distinct possibility of a fifth stage geared to aptitude variations and career commitments hypothesized by Piaget towards the end of his life.

Lastly, this construction and reconstruction of the proverbial elephant by the several workers is still shrouded in mystery. Miles gone and miles yet to go inside this mental territory to a great extent depend upon the appropriateness of the questions asked at the end of each journey. So to conclude aptly in the words of Prof. Margaret A. Boden :

The notion of representation that is central to Cognitive Science presupposes that individual minds have their own subjective views, or models, of the world. Some features of these models are shared, others are idiosyncratic; some are universal to the species, others are culture-specific; and some are innate, whereas others are learned by interaction with physical and social environment. But irrespective of these distinctions, they are all conceived of as essentially subjective or mental phenomena (variously accessible to conscious inspection or control), embodied in biological mechanisms that realize their representative and computational functions.

It follows that the image of men projected by Cognitive Science is one that not only allows but even stresses the subjectivity and interpretative power that are emphasized by humanist, hermeneutic, and mentalist approaches to philosophical psychology. Psychological theories are themselves models of mankind, by reference to which individual people deliberate, choose and act in daily life,' That is, they are constitutive of social reality as well as descriptive of it. Some critics have despaired of recent, "scientific" psychology, as in Sigmund Koch's judgment :

> That modern psychology has projected an image of man which is as demeaning as it is symplistic, few intelligent and sensitive non-psychologists would deny. To such men–whether they be scientist, humanist or citizen, psychology has increasingly become an object of derision. The mass dehumanization process that characterizes our

> time-the simplification of sensibility, homogenization of taste, attenuation of the capacity for experience-continues space. Of all fields in the community of scholarship, it should be psychology which combats this trend. Instead, we (psychologists) have played no small role in augmentating and supporting it.

But Cognitive Science can counteract the insidiously dehumanizing effects of the natural sciences and behaviourist psychology, which have no place for the notion of representation and so no place for such concepts as purpose, freedom, and moral responsibility....Cognitive Science (including the study of 'artificial' computational systems) can clarify the way in which intentions are structured and generated in the mind and have effects in bodily action, and so can help elucidate the computational basis of the specifically human concepts sketched above. Koch and like-minded critics of the dehumanizing influence of modern psychology should be less derisive about this new intellectual synthesis, for the image of man prejected by it is neither demeaning nor simplistic. Since Cognitive Science promises to show not only how knowledge and subjectivity are possible in a basically mechanistic universe, but how purpose, freedom, and morality are possible also, it offers a truly human psychology without denying our biological embodiment or losing sight of our evolutionary origins.

□

Chapter VI

The Developing View of Adolescent Thought

Introduction

Whereas intelligence has been a matter of conjecture from the earliest days of recorded history, the psychological investigation of thinking is a phenomenon of this century. In the nineteenth century, it was equated with knowledge and information. Historically speaking, the work on the likely construct of intelligence began in its nascent form during the closing decade of 19th century. It was, according to Charles Spearman, regarded as the general characteristic of man, expressed in 'g' plus specific factors like verbal, numerical and the very characteristics of the individual tasks. Using factor analysis, L. L. Thurstone hit at 12 factors which finally crystallized into six factors, viz., number, verbal, space, memory, reasoning and word fluency. Like Charles Dalton, J. P. Guilford, Using fact and fiction, developed the Model of Intellect along three dimensions, viz., Contents (4) Operations (5) and Products (6), thus, hypothesizing the existence of 120 individual factors out of which over eighty factors so far have been discovered in various research studies.

Eysenck provided a shorter cubical model comprising Test Materials (verbal, number, space), Mental Process (reasoning, memory and perception) and Quality (speed and power). Keeping firmly to the British tradition, P. E. Vernon pictured the differentiation of intelligence including creativity and a highly diminished Piagetian view without, of course, losing the relevance of 'G'. In his 1964 presidential address to the American Psychological Association, Quinn McNemor very badly criticized the concept of Primary Mental Abilities, and instead, suggested a social dimension, to the concept of intelligence as well. Raymond B. Cattell biclassified the factors into Crystallized Intelligence (experimental-educative-aculturative) and Fluid Intelligence (biological endowment). Where did this psychometric approach lead to ? Jokingly all this led to : Intelligence is that which is measured by the psychologist's test. Intelligence is now defined as an 'attribute of behaviour' rather than that of the individual i. e., much beyond interpretable bonds and stimulus-response convections etc., Consequently, I. Q. became a deviate I. Q. devoid of quotient which in turn became a misnomer. And in the phraseology of Alexander G. Wesman (1968) intelligence became intelligence testing, metamorphically speaking, like electron becoming electron finding in the history of atomic physics at whose bottom lies CONFUSION.

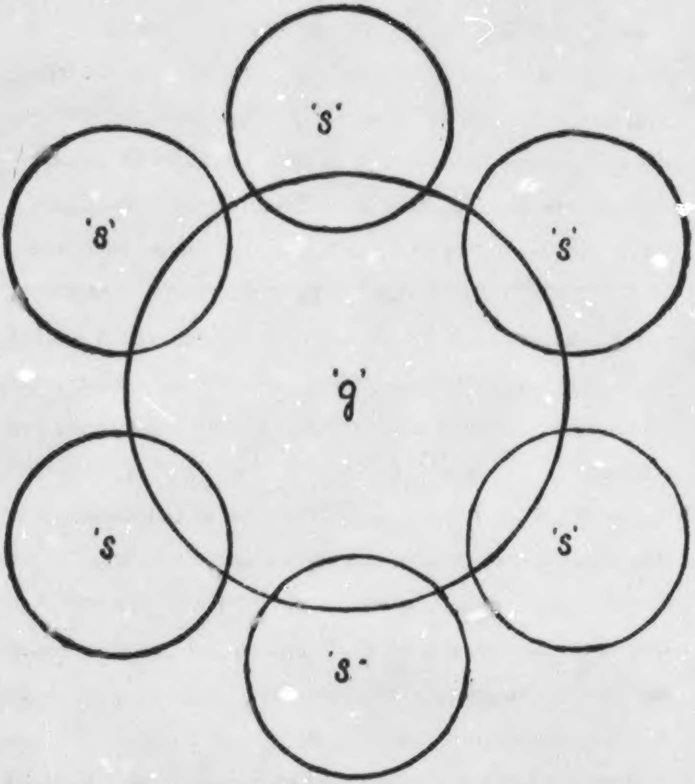
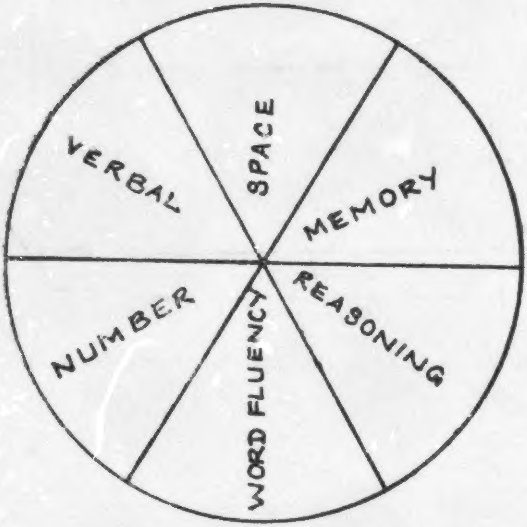
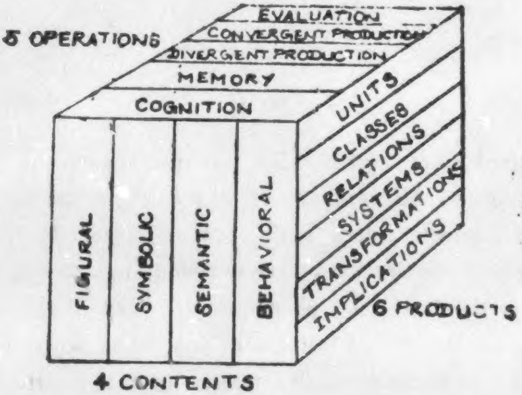


Fig. 3
Structure of Intellect—Spearman



VERBAL
SPACE
MEMORY
REASONING
WORD FLUENCY
NUMBER

Fig. 4
Structure of Intellect—Thurstone



5 OPERATIONS
EVALUATION
CONVERGENT PRODUCTION
DIVERGENT PRODUCTION
MEMORY
COGNITION
FIGURAL
SYMBOLIC
SEMANTIC
BEHAVIORAL
UNITS
CLASSES
RELATIONS
SYSTEMS
TRANSFORMATIONS
IMPLICATIONS
6 PRODUCTS
4 CONTENTS

Fig. 5
Structure of Intellect—Guilford

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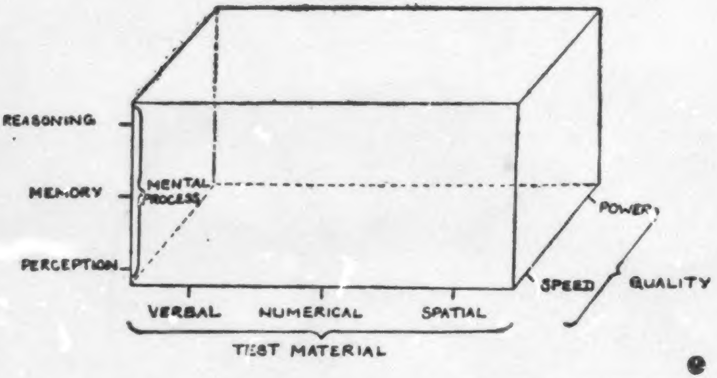
REASONING
MEMORY
PERCEPTION
MENTAL PROCESS
VERBAL
NUMERICAL
SPATIAL
TEST MATERIAL
POWER
SPEED
QUALITY

STRUCTURE OF INTELLECT AS PROPOUNDED BY EYSENCK

Fig. 6

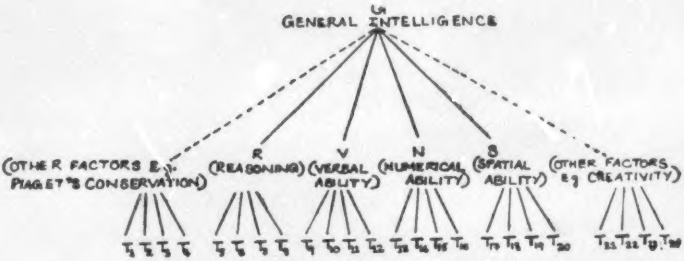
G
GENERAL INTELLIGENCE
R
(REASONING)
V
(VERBAL ABILITY)
N
(NUMERICAL ABILITY)
S
(SPATIAL ABILITY)
(OTHER FACTORS E.g. PIAGET'S CONSERVATION)
(OTHER FACTORS eg CREATIVITY)
T10
T11
T12
T20
T21
T22

Fig. 7

Alfred Binet perhaps said too much when he defined intelligence as the 'resultant of all the higher mental functions in complete interaction'. It was, therefore, necessary to rub the variables the otherway round, i. e., seeing intelligence as the developing phenomenon. Jean Piaget defined intelligence then as an instance of adaptation where life was seen as a continuous creative interaction between the individual and his environment (physical, mental and social). Here, the crystallized intelligence became out of tune in the pressence of schema, schemata or scheme of thought. Injecting stage concept into the growth of intelligence, he distinguished between Sensory Motor Intelligence and Reflective Intelligence with inbuilt five properties of logical groupings : combinativity, reversibility, associativity, nullifiability and tautology. Interestingly enough when clockwise and anticlockwise approach are aggregated with time as the variable, the fifth Piagetian stage was seen linked with aptitude variatiations and varied career commitments. If the basic underlying essence is captured, the concept of the Scheme of Thought does emerge which is easier tested through a series of problems each inhering a countinuous chain of reasoning in the problem solving context, for it is assured that all behaviour is Schematic in character which is another grand hypothesis.

The Distinguishing Characteristics of Scheme of Thought

Like electricity, it is inferred rather than observed. The main characteristics of the scheme of thought are :

(a) It is as simple as reflective activity and as complex as advanced problem solving plan. It thus grows and organises itself at different levels, both horizontal and vertical.

(b) It is invisible, that is, not open to direct observation. It is, therefore, inferred only.

(c) It assimilates as well as accomodates to external reality. Over the years, it is raised to the concept of its psychological counterpart.

(d) It does not develop in a vacuum. It is also not empty from inside. It is active as well as flexible having both context and form. The latter disciplines the former, for example, differentiated functions among the various components of the scheme are mutually inter-related, even compensation being no exception.

(e) In case of failure, another schema may become active for it is in the nature to act on a situation : physical or mental. This implies the existence of possible relationship among schemata. The very discrepant situation causes strain in the organism, which, meets it by the very growth of schema sooner or later. Otherwise, it shows its coordinating functions with greater possibilities for the transfer of generalized search strategies.

(f) Lastly. it reflects itself by a given behaviour sequence or in it, the very utilization of logical rules. These are, comparatively speaking, easy to determine from the very knowledge which is being investigated upon from the angle of psychological formation. It is, thus, easy to see that the schema becomes the set of equivalance implied by the behaviour of the subject not, of course, in any single sequence, for no equivalance could be inferred from any isolated observation.

The Piagetian Research Frontier

It is of interest to note that the final stage of intellectual development as defined by Piaget stands little explored. The research frontier as suggested by him is now mentioned below

S.No.	Scheme	Experiments
1.	Combinations	Chemical combinations, in a system containing a substance to be coloured, a dye, an inhibitor and a neutral agent.
2.	Proportionality	Equilibrium on a balance beam where the multiplicative relation between length and weight must be dealt with.
3.	Correlations and probability	Discovering the relations between a pair of imperfectly correlated variables (hair and eye colour).
4.	Conservation beyond empirical experience	Conservation of movement in a system containing some friction, i.e., rolling balls on a horizontal plane.
5.	Inversion and reciprocity coordinated in maintenance of equilibrium	Behaviour of liquid in communicating vessels (equality of water levels, relation between water pushed out of one tube and into the other).

S.No.	Scheme	Experiments
6.	Mechanical equilibrium.	Hydraulic press (a more quantitiative version of the preceding).
7.	Coordination of two reference systems	Snail moving on moving platform.
8.	Equilibrium of work mechanical proportion	Behaviour of wagon on variably inclined plane counter balanced by variable weights on pulley,
9.	Gemoetrical proportionality	Predicting size of shadow cast with objects varying in size and distance, screen and source varying in distance.
10.	Compensation of interacting variables	Behaviour of balls on rotating platform, relation between weight and distance from centre in determining centrifugal motion.

Some Other Models

1. Another cubical model was suggested by Frank E. Williams having three dimensions, viz , curriculum (all school subjects), teacher behaviours (much beyond interaction analysis, teaching methodology and other tactics), and cognitive as well as affective which is too difficult to handle for day to day classroom use.

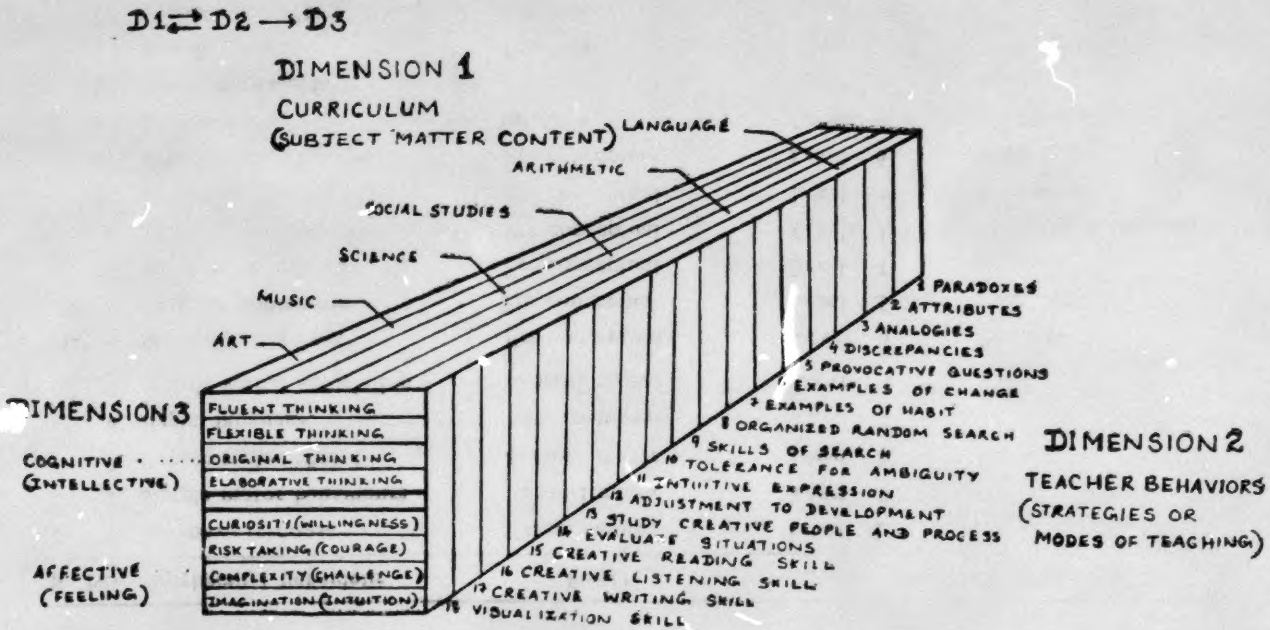
D1⇄D2 → D3
DIMENSION 1
CURRICULUM
(SUBJECT MATTER CONTENT)
LANGUAGE
ARITHMETIC
SOCIAL STUDIES
SCIENCE
MUSIC
ART
DIMENSION 3
COGNITIVE
(INTELLECTIVE)
FLUENT THINKING
FLEXIBLE THINKING
ORIGINAL THINKING
ELABORATIVE THINKING
CURIOSITY (WILLINGNESS)
RISK TAKING (COURAGE)
COMPLEXITY (CHALLENGE)
IMAGINATION (INTUITION)
AFFECTIVE
(FEELING)
1 PARADOXES
2 ATTRIBUTES
3 ANALOGIES
4 DISCREPANCIES
5 PROVOCATIVE QUESTIONS
6 EXAMPLES OF CHANGE
7 EXAMPLES OF HABIT
8 ORGANIZED RANDOM SEARCH
9 SKILLS OF SEARCH
10 TOLERANCE FOR AMBIGUITY
11 INTUITIVE EXPRESSION
12 ADJUSTMENT TO DEVELOPMENT
13 STUDY CREATIVE PEOPLE AND PROCESS
14 EVALUATE SITUATIONS
15 CREATIVE READING SKILL
16 CREATIVE LISTENING SKILL
17 CREATIVE WRITING SKILL
18 VISUALIZATION SKILL
DIMENSION 2
TEACHER BEHAVIORS
(STRATEGIES OR
MODES OF TEACHING)

Fig. 8
Model of Intellect as Propounded by Williams

2. When Robert Gagne's and L.S. Vygotsky's models are compared to that of J. Piaget's, the picture is as follows :

S. No.	Intellectual Behaviour	Piaget	Gagne	Vygotsky
I- 1.	Reflexive response	Sensori motor	Level 1	—
2.	Simple motor behaviours	Sensori motor	Level 2	
3.	Simple motor chains	Sensori motor	Level 3	
4.	Begin language.	Sensori motor	Level 2	
5.	Simple verbal association	Sensori motor	Level 4	
II- 6.	Symbolic meanings	Pre conceptual	Level 6	Phase of syncratic images : Trial and error stage; Perceptual stage; Composite stage.
7.	Task discrimination	Pre conceptual	Level 5	
8.	Extended sentences	Pre conceptual	Level 4	
9.	Motor verbal associations	Pre conceptual	Levels 3/4	
10.	Representations	Pre conceptual	Level 4	
11.	Transductive reasoning	Pre conceptual	Level 6	
12.	Causality	Intuitive	Levels 6/7	
13.	Number concepts	Intuitive	Level 6	
14.	Simple rules	Intuitive	Levels 4/7	
15.	Classifications/Non conceptual	Intuitive	Level 5	

S.No.	Intellectual Behaviour	Piaget	Gagne	Vygotsky
III-16.	Reversibility	Concrete operations	Level 7	Phase of complexes;
17.	Classifications/Concrete conceptual	Concrete operations	Level 6	Associate stage association;
18.	Seriation	Concrete operations	Level 7	Collection stage;
19.	Relationships	Concrete operations	Levels 6/7	Chaining stage.
20.	Mathematical computations	Concrete operations	Levels 6/7	Diffuse stage, pseudo
21.	Conservation	Concrete operations	Levels 6/7	conceptual stage.
IV-22.	Analysis	Formal operations	Levels 7/8	Phase of concepts
23.	Abstractions	Formal operations	Levels 6/7	(Puberty) : Stage of
24.	Hypothesizing	Formal operations	Levels 6/7/8	maximal similarities.
25.	Complex rules	Formal operations	Levels 7/8	Stage of concepts;
26.	Complex problem solving	Formal operations	Level 8	Stage of genuinine concepts.

Piaget has suggested a vast research frontier within his own school of thought which is yet to be appreciably scratched. Several authors combining both psychometric and developmental approaches have investigated adolescent thought but no clear-cut picture emerges because of poor mix of the very aims and objectives of the various studies, modes of sampling, restricted age ranges covered and the findings upon which sharp hypotheses could be based. But consistent with the spirit of science and technology, a short tunnel to learning may appear especially when high speed computers are at our disposal. The factorial position in regard to adolescent thought appears to be some what as follows:

S. No.	Factors	Psychological Interpretations	Author (s)
1.	First Factor	1. General Intellectual Factor	Abou Hatab (1964), Beard (1957), De Lemos (1969), Mac Arthur (1968), Peel (1955), Sandhu (1980), Staver and Gabel (1979), Tuddenham (1970), Vernon (1971), Vaidya and Sandhu (1981),
		2. Schematic Learning General	Bart (1971), Renner and Lawson (1975), Vaidya (1975), Jain (1982)
		3. Attainment Factor	Vaidya (1964)
		4. Algebraic Aptitude	Joshi (1970)
		5. General Adjustment	Vaidya and Misra (1975)
		6. Formal Operational Thought	Abramowitz (1975)
		7. Exclusion of Variables	Shayer (1978)
		8. Language Factor	Padmini (1982)

S.No.	Factors	Psychological Interpretations	Author (s)
2.	Second Factor	1. Practical Factor	Vaidya (1964)
		2. Symbolic Substitution	Joshi (1970)
		3. Adjustment	Vaidya (1975)
		4. Seeing the Problem as a Whole	Vaidya and Misra (1975)
		5. Piagetian Cognitive Development	Staver and Gabel (3978)
		6. Acadmic Achievement Factor	Sandhu (1980), Vaidya and Sandhu (1981)
		7. Creativity	Jain (1982)
		8. Exclusion of Variables (Testing of Hypotheses)	Padmini (1982)
3.	Third Factor	1. Interest Factor	Vaidya (1964)
		2. Problem Orientation	Vaidya (1975)
		3. Formulating Hypotheses	Vaidya and Misra (1975)
		4. Piagetian Logical Operations Test	Staver and Gabel (1979)
		5. Adjustment Factor	Sandhu (1980)
		6. Stating and Testing of Hypotheses	Vaidya and Sandhu (1981)
		7. Achievement	Jain (1982)

S.No.	Factors	Pscyhological Interpretations	Author (s)
		8. Exclusion of Variables (Stating of Hypotheses)	Padmini (1982)
4.	Fourth Factor	1. Adjustment Factor	Vaidya (1964)
		2. Sensing Problems	Vaidya (1975)
		3. Tackling Algebraic Symbols	Vaidya (1975)
		4. Interest in Generating Difficult Problems	Vaidya and Misra (1975)
		5. Behavioural Factor	Sandhu (1980)
		6. Super Ego Strength	Vaidya and Sandhu (1981), Padmini (1982)
5.	Fifth Factor	1. Problem Orientation	Vaidya (1975)
		2. Symbolization	Vaidya (1975)
		3. Newness of the Problem	Vaidya and Misra (1975)
		4. Emotional Factor	Sandhu (1980)
		5. Premsia	Vaidya and Sandhu (1981)
		6. Group Factor of Personality (Dominance, Guilt proneness, Ergic tension)	Padmini (1982)

S.No.	Factors	Pscyhological Interpretations	Author (s)
6.	Sixth Factor	1. Testing Hypotheses	Vaidya (1975)
		2. Using Constant Difference	Vaidya (1975)
		3. Temperamental Factor	Sandhu (1980)
		4. Self Sufficiency	Vaidya and Sandhu (1981)
		5. Permutations and Combinations	Padmini (1982)
7.	Seventh Factor	1. Aspect Character	Vaidya (1975)
		2. Using Constant	Vaidya (1975)
		3. Group Factor of Adolescent Thought–I	Sandhu (1980)
		4. Parmia	Vaidya and Sandhu (1981)
		5. Mechanical Reasoning	Padmini (1982)
8.	Eighth Factor	1. Exclusion of Variables	Vaidya (1975)
		2. Aspect Character	Vaidya (1975)
		3. Social Factor	Sandhu (1980)
		4. Adjustment	Vaidya and Sandhu (1981)
		5. Self Sufficiency	Padmini (1982)
9.	Ninth Factor	1. Combinatorial Grouping	Vaidya (1975)
		2. Seeing Problem as a Whole	Vaidya (1975)

S.No.	Factors	Pacyhological Interpretations	Author (s)
		3. Group Factor of Personality—I	Sandhu (1980)
		4. Space Relations	Vaidya and Sandhu (1981)
		5. Age	Padmini (1982)
10.	Tenth Factor	1. Intelligence	Vaidya (1975)
		2. Verbal Discription Procedures	Vaidya (1975)
		3. Abstract Thinking Factor	Sandhu (1981)
		4. Surgency	Vaidya and Sandhu (1981)
		5. Parmia	Padmini (1982)
11.	Eleventh Factor	1. Group Factor of Adolescent Thought—II	Sandhu (1980)
		2. Excitability	Vaidya and Sandhu (1981)
		3. Ego Strength	Padmini (1982)
12.	Twelfth Factor	1. Stating and Testing Hypotheses	Sandhu (1980)
		2. Intelligence	Padmini (1982)
13.	Thirteenth Factor	1. Group Factor of Personality—II	Sandhu (1980)
14.	Fourteenth Factor	1. Group Factor of Adolescent Thought—II	Sandhu (1980)

* Some factors from the bottom upwards could be eliminated through screetest.

An active eye can perceive immediately the following problems which are bound to explode and spin in the phraseology of atomic physics :

(a) How to bridge-in the gap between the knowledge gained from the study of intelligence in its developmental and psychometric aspects ?

(b) How to link schemes of thought with aptitudes ? What are their realizable potentials ? Because, the business of intervention both in formal and non-formal modes of education cannot be left to philosphical speculations.

(c) How to provide a firm mathematical picture regarding the nature and development of intelligence ?

Answers to these questions are little available even now, despite the availality of improved methodology, statistics and high speed computers. Metamorphically speaking, several workers all over the world engaged directly as well as indirectly in this business have to reconstruct the proverbial whole elephant again and again. The foundational picture of intelligence in its entirety is likely to depend upon mathematical structures which when put to test may clarify our foggy ideas about its nature. The psychometric effort of intelligence is, of course, fruitful now has revealed little and so about its genetic component in the famous heredity environment controversy for, Piaget, taking middle of the road policy, was not simply cooling his heels. If efforts are made to comprehend the questions raised above, a fundamental change in our view regarding the nature of intelligence must remain an exemplar when it comes to the merging of two oppositely differing findings, each leading to bagging a Nobel prize by Thompsons, father and son, over a thirty year period in this century especially when in the preceding century, Stoney in 1835 had conceived it as a basic unit of positive or negative charge. Taking a balanced view, like the varied concepts of electron, the varied facts of intelligences do meet individual requirements at the different levels of the educational laddar for workable purposes. Until then the fingers remain crossed because better conceptual distinttions can be drawn only when concepts in vogue along with their past history are clearly known. If not, it would be purely for the simple reason that factor analysis is a highly mathematical technique as well as educational technology having its own failings. The various factors failing to to appear in a definite way should not olny be searched for but also, later on, subjected to empirical testing by carrying out, highly imaginative studies using factorially known tests as reference points. The various tests used should cover as many diverse populations meeting fairly well the intended objective criteria of reliability and validity. Similarly, the sizes of the samples should not invariably be less than four times the number of tests used. After having done this, the growth of factors should be clinically explored and the same be checked empirically to test whether the findings come from different chips of different blocks or the different chips of the same block. Whatever be the nature of those findings, they are bound to alter the already proposed structures of intellect. A periodic table of intelligence like the one in chemistry, if it exists, may become available for the benefit of learning psychologists. Until then, as it is apparent, the studies documented above simply as well as superficially reflect the possible structure of adolescent thought as imaginatively proposed by the Geneva School, using symbolic logic. Lastly, it will not be out of place to mention that the role of hints and cues in the development of concepts as well as problem solving is yet to be investigated with focus on acceleration of thought along with the varied modes of presenting subject matters, a very worthy aim of any first class educational system anywhere in the world.

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APPENDICES

List of Contributors

S.No	Name and Address	Investigations
1.	Dr. Teg Singh Sandhu, Lecturer, Department of Education and Community Services, Punjabi University, Patiala, Punjab.	*Factorial Study of Adolescent Thought Using Piaget Type Tasks (Loaded with Scientific Contents).
2.	Shri S. C. Jain, Lecturer, Department of Physics, Regional College of Education Ajmer-305004 Rajasthan.	*(i) A. Study of Problem Solving Behaviour in Physics During Adolescence. (ii) Conservation of Mass, Weight and Volume.
3.	Miss Padmini M. S. Research Fellow, Department of Education, Regional College of Education, Ajmer-305004 Rajasthan	*(i) The Growth of Exclusion of Variables During Adolescence-A Study. *****(ii) Varied Thumb-nail Studies and Findings
4.	Shri R. M. Misra Regional College of Education, Ajmer.	**The Role of Hypotheses in Solving Problems of Science.
5.	Miss Leela Kansakar 14/82, Pyafal Tole, Kathmandu (Nepal)	**The Formulation and Testing of Hypotheses During Adolescence.
6.	Miss Ann Mary Jacob Lecturer, Teachers College Vidhya Bhawan, Udaipur, Rajasthan	**Some Aspects of Concept Formation and Intellectual Development.

S.No.	Name and Address	Investigations
7.	Miss Madhu Mathur 186/10, Nagina Bagh Ajmer.	**The Formation of Experimental Mind During Adolescence.
8.	Mrs. Avinash Grewal Lecturer in Education, Regional College of Education, Bhopal	**A Study of Relationship Between Hypotheses-Testing Ability in Science and Creativity.
9.	Miss Vandana Raizada, C/o Dr. B. S Raizada, Lecturer in Education, Regional College of Education, Ajmer-305004 (Rajasthan)	**A Study of Relationship Between Problem Solving Ability and Some Relative Personality Traits Using Piagetian Tasks.
10.	Shri Gurbans Singh Bhawa, M. Phil (Student) Department of Education, and Community Services, Punjabi University, Patiala, Punjab.	***The Effect of Training on Formal Operation Thought : Stating and Testing Hypotheses.
11.	Dr. K. C. Jindal, Govt. College of Education Chandigarh.	****Child's Conception of Movement (An Emperical Study)

*Based upon the doctoral work under the guidance of the author

**Based upon M. Ed work under the guidance of the author largely speaking.

***Based upon M. Ed. work under the guidance of Dr. T. S. Sandhu.

****Based upon the doctoral work under the guidance of Prof. J. N. Joshi.

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List of College Publications

1. Activities of Science Sponsors Vol. I to IX.
2. Innovative Ideas and Practices in Education : Series 1 and 2.
3. Strategies in Science Education,
4. Programme Learning : Monograms.
5. Programme Learning Series.
6. Emerging Perspectives in Science Education.
7. Bibliography on Science Education.
8. Lesson Planning Booklets in Different Subjects.
9. Ten Year Schooling : A Framework in different Regional Languages.
10. Seminar Reports.
11. Research in Science and Mathematics Education.
12. Educational Trends Vol. I to XIII.
13. Extension Lectures.
14. Some Aspects of Teaching English.
15. Planning for Science Teaching.
16. Guiding the High School Students.
17. Institutional Planning.
18. Concept Formation.
19. Teaching of Mathematics—a point of view.
20. The Emerging Psychological Frame of Reference for Our School Science Education.

21. The Mathematical Structures Underlying Adolescent Thought.
22. The Piagetian Journey.
23. The Nature and Development of Problem Solving Behaviour in School Science Through Environmental Education During Adolescence.
24. Let Grammar Come To Them
25. Course Blue Prints of Programmes on "A" and "An"; "The"; "Some"; "Any".
26. Use of "The"—A Progammed Instructional Material.
27. Interaction Analysis : Theory and Research.
28. The Piagetian Journey (Revised)